Macroeconomics at a Crossroads: Paradigm Shifts and New Approaches

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Editör: Dr. Öğr. Üyesi Burçin ÇAKIR GÜNDOĞDU

Gazi Kitabevi



"En İyi Akademi, Bir Kitaplıktır."

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Macroeconomic Stability and Inclusive Growth: A Holistic Approach to Reducing Income Inequality

Dr. Öğr. Üyesi Duygu ÇELİK

Abstract

A review of the economics literature reveals that in earlier periods-characterized by more traditional approaches-the primary objectives of economies were defined as achieving economic growth and macroeconomic stability. Concepts such as income distribution equity and economic inclusivity had not yet received sufficient attention. However, the transformations the global economy has undergone over time have led to shifts in these objectives. Global crises and the accompanying rise in income inequality have gained prominence in economic literature and sparked significant debate. Consequently, it has become evident that an economy requires not merely growth, but inclusive growth. This study examines the relationship between macroeconomic stability and inclusive growth from both theoretical and empirical perspectives, ultimately addressing the policy implications. The study discusses Kuznets' Inverted-U hypothesis, Piketty's analyses of capital accumulation, and endogenous growth models. Furthermore, it explains various income inequality measurement methods, such as the Gini coefficient, the Palma ratio, and the Theil index. Towards the end, the study analyzes the impact of various monetary and fiscal policies on income distribution. It also evaluates the effects of ''Twin Transition'' processes on income inequality and employment. The study concludes that markets do not spontaneously generate an environment for inclusive growth; rather, the implementation of ''pre-distribution'' policies aimed at reducing inequality is essential. It emphasizes the necessity of establishing inclusive institutions and social protection policies.

Keywords: Inclusive Growth, Macroeconomic Stability, Income Inequality, Fiscal Policy, Twin Transition

1. Introduction

Countries' development strategies primarily focus on macroeconomic stability and economic growth. Nevertheless, the 2008 Global Financial Crisis and its aftermath clearly demonstrated that wealth cannot be achieved solely through increased national income. Nowadays, if economies want to achieve macroeconomic stability, they need to focus not only on growing national income but also on matters such as the equitable distribution of that income, equal opportunities, and poverty decline. All these concepts can be perused within a holistic approach under the heading of ''inclusive growth.''

Economic growth and income inequality have been basic focal points studied since the earliest periods of economic history, undergoing various transformations. When inspecting traditional macroeconomic theories, the best-known classical approach is the theory put forward by Kuznets (1955). Kuznets (1955) studied the development stages of a country and stated that in the early stages of development, as economic development increases, income inequality will also increase. However, he indicated that this relationship would reverse once per capita income reaches a certain level. That is, after this stage, as economic development increases, income inequality will decrease. This results in a graphical ''inverted U'' shape. Kuznets' inverted U hypothesis is one of the best-known theories in economic history.

At the turn of the 21st century, new empirical evidence began to emerge on this issue. Newly developed micro-data sets profoundly challenged these traditional assumptions. Piketty (2014) pointed out that the rate of return on capital has been higher than the rate of economic growth, revealing that this structurally deepens wealth and income inequality. This study also opened the door to new global debates. Unlike traditional theories, modern endogenous growth models state that high and persistent inequality negatively impacts economic growth. Galor and Zeira (1993) argue that inequality, due to imperfections in financial markets, prevents poor segments of the population from investing in human capital such as education and healthcare. They also show that this restricts long-term productivity increases. Recent studies by institutions such as the International Monetary Fund (IMF) and the OECD also support this view. Ostry, Berg, and Tsangarides (2014) conducted an analysis based on a broad panel of countries. Accordingly, it has been proven that low net inequality levels after taxes and transfers not only lead to higher economic growth but also ensure that growth periods are much longer lasting. Similarly, Dabla-Norris et al. (2015) stated that an increase in the income share of the top 20% income group slowed GDP growth. However, conversely, they showed that an increase in the income share of the bottom 20% and the

middle class statistically affected the growth in a significant and positive manner. All these findings reveal that income inequality is not only a social issue but also necessary for macroeconomic stability (Cingano, 2014).

The shifts observed in historical findings clearly indicate that the new focus should be on ‘’inclusive growth‘’ rather than traditional growth. Inclusive growth is a concept far beyond simply exhibiting pro-poor growth. It also includes the participation of the poor in economic growth processes and the creation of equal opportunities (Anand, Mishra, and Peiris, 2013). Hence, this section of the book aims to comprehensively peruse macroeconomic stabilization policies and their relation with income distribution. The survey will proceed through three main parts. The first involves fiscal transmission channels. Viewed through this lens, the influence and capacity of taxation systems, public expenditures, and social transfer mechanisms on income redistribution will be inspected. The second part will address monetary and financial transmission mechanisms. Within this framework, how monetary policies, framed by central banks, influence the poor through means such as inflation and interest rates will be explored. The final stage will address necessary structural transformation processes and labor markets. The hindering influences of technological development, the informal economy, and labor market rigidities on inclusive development will be discussed. The aim of this survey is to propose a holistic set of macroeconomic policies that will strengthen the social fabric by improving not only quantitative growth but also the quality of growth.

2. Theoretical Framework

Throughout economic history, the relation betwixt growth and income distribution has evolved through many stages. As time progressed, periods, socio-economic conditions, and analytical tools varied. This led to the inspection of the relation betwixt economic growth and income distribution from different perspectives. Throughout economic history, the question of whether income inequality has a positive or negative influence on economic growth has been continuously studied. In more recent times, the argument surrounding the necessity of distribution for macroeconomic stability has intensified, adding new dimensions to the discussion.

Classical economics addressed income distribution through the lens of factors of production. It established a framework of ‘’functional income distribution ‘’ where labor, capital, and natural resources played a leading role. Ricardo (1821), a prominent representative of classical economics, explained the limits of

economic growth through the law of diminishing returns and the increase in rent. According to Ricardo, economic growth favors capitalists (profit) and landowners (rent). Workers receiving wage income are at a disadvantage in this distribution. The most prominent macroeconomic model regarding the growth-inequality relationship within the classical approach was later put forward by Kaldor (1955). According to the Kaldor model, the marginal propensity to save of capitalists is much higher than that of workers. In this context, if income distribution is distributed in favor of capitalists, who are the upper income group, total savings in the economy will increase because this group saves more. When total savings increase, investments in the economy will also increase accordingly. Thus, macroeconomic growth will occur. From this, it can be inferred that income inequality is necessary for capital accumulation and economic growth to occur in an economy.

In neoclassical growth theory, the Solow (1956) model, which forms the basis of this theory, states that there is a distinction between growth and income distribution. Under the assumptions of perfectly competitive markets, flexible prices, and constant returns to scale, each factor of production obtains a return equal to its marginal productivity. In this model, economic growth is associated with external technological developments. It argues that there is no relationship between the growth rate and income distribution in the long run. In the periods and economies where this approach was adopted, macroeconomic policies focused on increasing productivity. Income distribution and allocation problems were therefore relegated to the secondary plan.

By the late 1980s, the rigid assumptions of the neoclassical model began to loosen. The new star of this period was endogenous (internal) growth theories (Lucas, 1988; Romer, 1986). Endogenous growth theories brought new perspectives to the economy. Primarily, the concept of capital ceased to be solely physical machinery and equipment; the concept of ‘’human capital ‘’ encompassing concepts such as knowledge, skills, education, and health, took its place. This theory explains how income inequality hinders economic growth. According to this theory, financial markets may not function efficiently due to incomplete information and asymmetric data. In this case, lower income groups may struggle to finance productivity-enhancing human capital investments such as education and healthcare. Galor and Zeira (1993) demonstrated that high inequality, in the presence of credit constraints, prevents a large segment of society from investing in human capital. Therefore, the productivity level of the economy decreases. As a result of all this, the long-term growth potential of the economy is permanently reduced.

According to models developed by Alesina and Rodrik (1994) and Persson and Tabellini (1994), high income inequality increases demands for redistribution in society. According to this model, if an economy has high income inequality but a democratic system, lower- and middle-income groups can exert political pressure to increase taxes on capital. When tax rates rise as a consequence of this pressure, it disrupts investment incentives and ultimately decelerates economic growth. Hence, according to endogenous models, inequality both hinders human capital accumulation at the micro level and distorts fiscal policy at the macro level, creating a negative and asymmetrical pressure element on growth.

When discussing economic growth and income inequality, the theory at the forefront is doubtless Kuznets' (1955) Inverted-U Hypothesis. According to Kuznets' hypothesis, an economy embarks to develop economically, especially when it begins to transition from an agricultural to an industrial society. These are the early stages of development. At this stage, Kuznets stated that income inequalities would increase. Nevertheless, in later periods, the status will gradually decline with urbanization, the spread of educational opportunities, and the implementation of welfare state policies. Kuznets declare that inequality would drop after a certain peak point. Nevertheless, Kuznets' theory is now considered an optimistic theory. Although this theory was supported during the ‘’Golden Age‘’ period in developed economies in the mid-20th century, global developments since the 1980s have affected the acceptability of this hypothesis. Modern macroeconomic literature now assumes that the Kuznets curve is shaped by structural shocks and policy choices. Piketty's (2014) critique of inequality dynamics is of critical stature. In his work, Piketty used long-term historical data and proved that the rate of return on capital is structurally higher than the growth rate of the economy. This specifies that wealth inequality will not correct itself spontaneously within market dynamics but will instead deepen.

The new and modern macroeconomic literature also explains the current increase in inequality that the Kuznets hypothesis cannot explain. One of these new contributions is the phenomenon of Skill-Biased Technological Change. Acemoglu (2002) states that developments in automation and information technologies have increased the demand for skilled labor. Consequently, wages have also increased. However, he modeled that this also pushes unskilled labor performing routine tasks out of the market, thus making wage inequality permanent. Another contribution of the new macroeconomic literature to income inequality is related to the processes of globalization and financialization. With globalization, financial processes accelerate capital flows and make them even more free. This weakens the bargaining power of labor in the market. This modern theoretical framework reveals that inclusive growth is too complex to be left to

the ordinary course of the market. Active macroeconomic interventions are required to achieve inclusive growth.

3. Inclusive Growth: Conceptual Dimensions and Measurement Methods

Inclusive growth refers to a development model where, while countries exhibit macroeconomic economic growth, the effects of this growth permeate the entire population, increasing societal well-being. In the literature, it is also referred to as the ‘’pro-poor growth model‘’. However, there are significant differences between the two fundamental concepts. Pro-poor growth primarily examines whether there is an increase in income levels for those below the poverty line. On the other hand, it does not focus on the other segments of society who are not below the poverty line (Pernia, 2003). The concept of inclusive growth, however, has a broader perspective. Inclusive growth does not focus solely on poverty reduction. Anand, Mishra, and Peiris (2013) state that inclusive growth is a multi-dimensional concept and cannot be reduced solely to poverty reduction. This concept also includes the social fabric of the growth process, its job creation capacity, and equality of opportunity.

Ianchovichina and Lundström (2009) outlined the theoretical framework for this issue, stating that for inclusive growth to occur, macroeconomic growth must be spread across a broad base. They also stated that inclusive growth should encompass all sectors of the economy, especially labor-intensive sectors. Growth rate alone is not a sufficient indicator for inclusive growth; it also requires other indicators. These include:

1. A productive employment process: As a result of economic growth, productivity in the economy should increase and new job opportunities should be created.
2. Equality of opportunity: Broad-based access to education and health should be ensured, and the exclusion of labor-intensive sectors should be prevented.
3. Social Security System: Financial transfer mechanisms that protect the poor, who are vulnerable to crises and shocks that may occur in the markets, should be implemented.

Achieving inclusive growth does not only mean receiving a fair share of the national income created. It also includes contributing fairly to economic growth itself. Therefore, supporting the vulnerable segments of society with external

social support alone is not sufficient. The internal dynamics of macroeconomic markets should be shaped in this direction.

3.1. Macroeconomic Indicators Used to Measure Inequality

Precise measurement of income distribution is pivotal for revealing the true effects of inclusive growth. Countless methods exist in the literature for this motive, but each measurement method relies on different techniques and sensitivities.

- **Gini Coefficient and Lorenz Curve:** The Gini coefficient is one of the most commonly used measures of income inequality in macroeconomic analysis. It is frequently found in international datasets, including World Bank datasets and the SWIID. The Gini coefficient is calculated by determining the geometric shape between the Lorenz curve and the line of perfect equality, which is a 45-degree line. Figure 1 shows the Gini coefficient and the Lorenz curve.

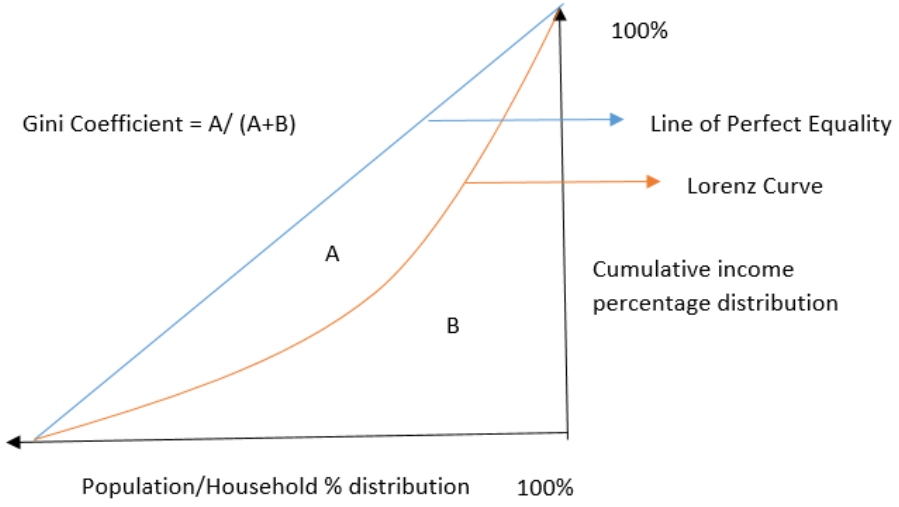


Figure 1: Gini Coefficient and Lorenz Curve

Figure 1 shows the Lorenz curve and the Gini coefficient derived from it. The Gini coefficient takes a value between 0 and 1. 0 represents perfect equality, while 1 indicates perfect inequality. A Gini coefficient is calculated for each country. Accordingly, the closer this coefficient is to 0, the more equitable the income distribution is in that country. Conversely, the closer the coefficient is to 1, the

greater the income inequality is in that country. The Gini coefficient, frequently used in measurements, has a weakness. This coefficient is highly sensitive to changes in the situation of middle-class households in the middle of the distribution, while it is less sensitive to changes in the situation of groups at the edges, representing the poorest and richest parts of society (Deaton, 2018). This situation can make the Gini coefficient insufficient for measuring the rapid accumulation of wealth in the highest income group, especially during periods of financial crisis.

- **Palma Ratio:** The Palma ratio was developed by Palma (2011) as a response to criticisms of Gini's approach. In his research, Palma (2011) used global datasets and conducted a study on the development levels of countries. As a result, he showed that the share of national income received by the middle class, located between the 7th and 9th deciles, remained constant at around 50% for all country types. Based on this, he stated that macroeconomic inequality is actually shaped between the richest 10% and the poorest 40%. The Palma Ratio was born in this way and is calculated by dividing the income share of the top 10% by the income share of the bottom 40%. The strength of the Palma Ratio is that it can reveal the tail effects, which are necessary to determine whether economic growth is pro-poor, more clearly than Gini's approach. Therefore, we see that the Palma Ratio is used more frequently in recent income inequality studies (Cobham and Sumner, 2013).

- **Generalized Entropy and Theil Indices:** The Theil index is derived from information theory. It is particularly used in regional economics and macroeconomic structural transformation analyses. The most important advantage of the Theil index, a measure of generalized entropy derived from information theory, is its ‘’decomposability‘’ property. That is, it can mathematically divide the total inequality in an economy into between-group inequality and within-group inequality (Shorrocks, 1980). For example, the Theil index can be used to decompose how much of the total income inequality in a country stems from differences between the agricultural and industrial sectors and how much stems from wage differences among workers within the same sector. This feature allows for more specific studies.

- **Atkinson Index (Welfare-Based Approach):** Atkinson (1970) introduced a different perspective on measuring inequality. This indicator includes the moral and social tolerance of society towards inequality. This is expressed with an inequality avoidance parameter. This parameter takes a value between 0 and +infinity. 0 represents complete indifference to inequality. +Infinity represents the Rawlsian approach that aims only to maximize the welfare of the poorest. The Atkinson Index measures how much of the total income would have to be sacrificed to reach the current level of welfare if income in an economy were distributed equally. When inclusive growth policies are implemented, it is possible to use this index to assess the extent to which they have increased social welfare.

- **Functional Income Distribution Indicators (Labor and Capital Shares):** This indicator examines how total income is distributed among factors of production. That is, it examines the shares of labor and capital in national income. Karabarbounis and Neiman (2014) state in their study that the share of labor in national income has continuously decreased globally since the 1980s. Therefore, when formulating policies within the framework of inclusive growth, importance should be given to changes in the share of labor as much as to indicators such as Gini and Palma.

4. Macroeconomic Transmission Mechanisms of Inequality

For many years, it was assumed that macroeconomic policies had no effect on income distribution. The focus of macroeconomic policies was on economic growth and stability. However, a review of the current literature clearly shows that this is not the case. Monetary and fiscal policies prepared and implemented by economic authorities can directly or indirectly affect income and wealth distribution in the economy.

4.1. Fiscal Policy: Taxation, Government Expenditure, and Transfer Systems

Fiscal policy is a macroeconomic tool organized by the government, through which the state redistributes income. Before the state intervenes in the market with fiscal policies, the spontaneously occurring income distribution in the market is

called market inequality. The state intervenes in this system within the framework of fiscal policies by using taxes and public spending, and makes a number of changes. The new situation that arises in the market as a result of this intervention is called net inequality. The effect of fiscal policy on inclusive growth is measured by the size of the gap between these two concepts (Ostry, Berg, and Tsangarides, 2014).

The rate of taxes in an economy has a significant impact on income distribution. Basically, there are direct taxes such as income and corporate taxes, and indirect taxes such as VAT and excise taxes. If direct taxes are more prevalent in an economy, this creates positive effects in terms of income distribution. Thus, a transfer of resources from the upper income group to the lower income group is possible. However, if the rate of indirect taxes is higher, this will have the opposite effect. The lower income group will be disadvantaged. Piketty and Saez (2003), in their study focusing on developed countries, found empirical evidence supporting this situation.

The other arm of fiscal policy includes government spending and transfer payments. The government makes investments by allocating resources to areas such as education, health, and infrastructure. This creates equal opportunities by supporting the accumulation of human capital for low-income individuals. Bastagli et al. (2012) found that poverty is reduced through public social security services and transfer payments. In addition to this finding, they also state that these systems provide stability against various macroeconomic shocks. In the model estimated using data from developing countries, it has been proven that fiscal transfers significantly reduce net inequality without harming growth potential.

4.2. Monetary Policy and Distributional Effects: Inflation and the Asset Price Channel

Monetary policies implemented by central banks cause changes in inflation and interest rates, affecting different income groups. In the economic literature, inflation is sometimes referred to as a ‘’hidden tax,‘’ as it has a particularly negative impact on low-income groups. Albanesi (2007) states in his study that low-income groups generally remain in cash and demand deposits, while high-income groups have easy access to financial assets that protect them against inflation. When high inflation is experienced, it directly reduces the already low purchasing power of the poor, thus exacerbating income inequality.

Following the 2008 global crisis, the world generally began implementing expansionary monetary policies. This also affected income distribution. Coibion et al. (2017) state in their study that expansionary monetary policies lower interest rates, resulting in increased demand for financial assets and higher prices. Financial assets are generally owned by high-income groups. Thus, monetary policy makes wealth and income distribution even more unequal, enriching the wealthy even more. On the other hand, a different outcome also occurs. Lower interest rates lead to a decrease in loan interest rates, easing the debt burden of the lower-middle income group. This also contributes positively to income distribution. However, studies show that this positive effect is quite limited compared to the negative impact of inflation in financial asset prices on income distribution.

4.3. Labor Market Structure, Technological Change, and Informal Economy

One more fundamental macroeconomic phenomenon defining income inequality is structural and technological transformations. These developments directly influence the share of GDP received by labor. One of the principal terms explaining labor and capital substitution in macroeconomic theory is Skill-Biased Technological Change. First introduced by Acemoglu (2002), this theory argues that technological progress increases the marginal productivity of skilled labor. However, it does not positively contribute to unskilled labor performing routine tasks; in fact, it excludes them from the system. With the expansion of capital-intensive production processes, ‘’skill ‘’ has become even more sought after, shaping wage distributions accordingly.

In addition, there has been a decline in unionization rates recently. The increasing flexibility in labor markets weakens labor's bargaining power against capital. Jaumotte and Osorio Buitron (2015), in their comprehensive research, demonstrated that the weakening of labor market institutions leads to income inequality in developing economies, reducing the share of national income received by labor.

One of the main reasons for the chronic nature of income inequality in developing countries is the problem of the informal economy. La Porta and Shleifer (2014), in their research, state that the informal sector is generally geared towards low-productivity, precarious, and low-wage labor. When informality is high in an economy, the taxes collected by the state will not be sufficient, leading to increased taxes. This, especially in an economy heavily reliant on indirect taxes,

will further reduce the income of those with low-income levels. This situation causes structural inequality to become a self-reinforcing vicious cycle.

5. Global Shocks, Crises, and Macroeconomic Vulnerabilities

Macroeconomic inequalities in an economy are not solely caused by long-term structural factors. While structural factors such as technological change and tax policies play a significant role in the emergence of inequalities, internal and external shocks experienced by economies over time are equally important. The 2008 Global Financial Crisis, the COVID-19 pandemic, and the subsequent global inflationary shocks have brought income inequalities back to the forefront. Thus, it has been observed that macroeconomic fluctuations disrupt income distribution not temporarily, but permanently. Therefore, to ensure the success of inclusive growth strategies, it is crucial to exhibit a structure resilient to the effects of macroeconomic shocks.

Macroeconomic crises can have an asymmetrical influence on dissimilar income groups. During crisis periods, the incomes of labor and capital do not experience the same kind of developments. Crisis periods create capital income to increase while labor income declines. This generates an asymmetrical effect. This asymmetrical influence displays the fundamental situation that leads to a further expansion in income inequality. Traditional macroeconomic theories forecast that profit margins and asset prices will fall during periods of economic recession, thereby reducing income inequality. Nevertheless, empirical outcomes from the modern era display that this is not the case. In their survey, Furceri and Loungani (2018) inspected the shocks and banking crises experienced during periods of financial liberalization. They conducted a comprehensive panel data analysis. The outcomes display that the Gini coefficient increases significantly during crisis periods. Alias, income inequality increases permanently during these periods. Labor income decreases. The lack of sufficient savings and limited access to credit for lower and middle-income groups is one of the foremost factors causing this inequality to deepen. During periods of contraction, job losses are generally concentrated amongst low-skilled and precarious workers. After a crisis, expansionary monetary policies are usually executed. These policies boost the prices of financial assets and transfer wealth to higher income groups. Thus, upper income groups who experience monetary losses during the harshest periods of the crisis quickly, and sometimes even more so, replace these losses in the aftermath of the crisis (Stiglitz, 2015).

Besides, inflationary shocks are another notable factor influencing income inequality. Unexpected inflation spikes lead to a real erosion of nominal wages due to wage elasticity. Crucial consumption items such as food and energy, in particular, constitute a large portion of the budgets of lower income groups. When an inflationary shock occurs, it directly decreases the income level of low-income groups even further. Globally, developing economies are amongst the countries that feel the effects of macroeconomic shocks most clearly. These countries are highly sensitive to global financial cycles. For instance, when the Federal Reserve (FED) implements a tightening monetary policy and raises interest rates, this leads to a rapid capital outflow from developing countries. Local currencies depreciate, and exchange rate crises also appear (Mendoza, 2010). As a consequence of these progress, economic actors in developing countries try to keep safe themselves by implementing contractionary policies. During such periods, they have hassle accessing external financing. They also implement austerity policies to sustain macroeconomic stability. Agnello and Sousa (2012) explored the influence of such periods on income distribution. Their research found that when the government cuts spending, this initially influences social transfers, education, and health investments. This leads to increments in income inequality.

Such structural asymmetries can be tested using sophisticated econometric methods. In recent literature critique, cross-sectional dependence is a particularly tested topic. Especially when a survey has a large time series and a multi-country sample, robust research is conducted using dynamic estimators such as the Generalized Method of Moments (GMM) and Panel ARDL. These surveys demonstrate that financial development enlarges inequality until a certain threshold is exceeded. Nevertheless, countries with strong and inclusive institutional structures weather these shocks with much less damage during crises. Countries with powerful pension or insurance systems, specially, find it easier to get better of these influences (De Haan and Sturm, 2017). In summation, achieving macroeconomic stability in developing countries requires more than just focusing on inflation and economic growth. The resilience of household balance sheets to shocks is also pivotal.

6. Twin Transformation and Inclusion from a Macroeconomic Perspective

In recent years, macroeconomic theories and policy enforcement have been caught in a quandary. A process known in the literature as the ‘’Twin Transformation ‘’ targets to bring together digitalization and green energy, making them reciprocally supportive processes. The Twin Transformation doesn't just influence production functions or technological infrastructure in an economy; it also influences income distribution. Historically, many technological shocks have occurred since the Industrial Revolution. These shocks have generally led to the creation of new employment opportunities in the long term, resulting in inclusive growth. However, the same is not true for the Twin Transformation concept and macroeconomic transmission mechanisms. Twin Transformation processes can contribute to income inequality.

Looking at digital transformation processes, the clearest impact of digital transformation on macroeconomic inequalities is on labor markets. Traditional models consider technological development to be a situation that increases labor productivity. Because it simultaneously changes all wages upwards, it is considered a neutral shock. However, current studies and their findings show that this is not actually the case. The impact of digitalization processes on income distribution is not neutral; on the contrary, it exacerbates income inequality. Today, a concept called ‘’Routine-Biased Technological Change‘’ (RBTC) is being discussed. This concept emerged as a reaction to the previously accepted concept of ‘’Skill-Biased Technological Change‘’. This new concept was first used by Autor, Levy, and Murnane (2003). According to this concept, digital technologies and automation perfectly replace ‘’routine‘’ tasks. However, they are unsuccessful in ‘’non-routine cognitive‘’ tasks requiring complex problem-solving and social intelligence. From a macroeconomic perspective, this situation causes manufacturing workers, office workers, and those performing routine jobs such as accounting to be disadvantaged by these processes. Digitalization processes lead to the exclusion of these groups from the market. Thus, a polarization begins in the labor market. Highly skilled professions and low-skilled but non-routine manual jobs such as cleaning and maintenance services increase their share in employment. In addition, middle-skilled jobs, which are the backbone of macroeconomic stability, are disappearing (Goos, Manning, and Salomons, 2014).

Polarization in the labor market distorts income distribution through a channel called the skill premium. As a result of digitalization processes, the income of highly skilled labor increases while the wages of low-skilled workers are

suppressed. Goldin and Katz (2007) comment on this, stating that ‘’inequality is a race between technology and education‘’. If sufficient human capital cannot be produced as a result of quality education, and digital technologies advance much faster, then skilled labor gains value and the skill premium increases. Acemoglu and Restrepo (2018) also state that artificial intelligence and automation remove labor from the production function, creating a ‘’displacement effect‘’. If the labor displaced as a result of technological developments cannot take on new and more productive tasks, then the share of labor in national income will permanently decrease.

Another consequence of digitalization processes is that they lead to capital intensity. Large firms, considered giants in their sectors, operate with almost zero marginal costs. As these firms grow, their share in the economy increases. As these capital-intensive firms grow, the share of labor in the market declines. In other words, digitalization leads to wage disparities among workers and a deterioration in the income distribution between labor and capital (Autor et al., 2020).

Another stage of the Twin Transformation processes is the ‘’green transformation‘’ which involves reducing carbon emissions and achieving zero-emission targets. Green transformation processes are a macroeconomic necessity for environmental health. However, in the short and medium term, they can also contribute to increasing income inequality. The most fundamental policy tools of green macroeconomics are carbon taxes and emission trading systems. Carbon taxes can have a negative impact on household income. Low-income households have a much higher share of energy-intensive consumption items such as heating, electricity, and transportation in their budgets compared to high-income households. Metcalf (2019) clearly demonstrates this in his study. He states that when a carbon tax is implemented, it increases the cost of energy-intensive consumption items such as food, heating, and transportation, which are essential items for lower income groups. Thus, there is an erosion in the income level of the lower income group. Therefore, planning should be done on how to redistribute tax revenues to the base. Otherwise, these results can lead to social problems and macroeconomic instability.

Another factor that increases income inequality can be the macroeconomic support provided within the scope of the green transformation. Government subsidies for expenditures such as electric vehicle purchases, rooftop solar panels, or energy-efficient building insulation generally go to middle- and upper-income groups. This is because these groups have the financial means to finance the initial payments for such ‘’expensive‘’ technologies. Borenstein and Davis (2016) state

that a large portion of green tax breaks and incentives are channeled to the top 20% income bracket. This empirically displays that public resources are used to subsidize the wealthy. This highlights the contradiction betwixt inclusive growth and the current structure of green macroeconomic incentives.

With green transition processes, resources are being reallocated. There is a move from ‘’dirty‘’ industries such as coal, oil, heavy industry, and engine manufacturing to renewable energy and clean technology sectors. This operation removes millions of jobs and creates new jobs requiring new skills. Nevertheless, this transition can be painful. Workers in dirty industries are almost always moderately skilled individuals with high unionization rates and earning middle-class wages. The surplus labor force created by the contraction of these sectors cannot easily transition directly to ‘’green jobs‘’ requiring high qualifications or different regional locations (Vona et al., 2018). Hence, persistent unemployment can appear in some regions, leading to increased regional inequalities. Hence, the macroeconomic influences of the Twin Transformation, if left to their own devices, scupper inclusivity. It is necessary to both abate the polarization created by digitalization and to equitably distribute the cost of the green transformation. This calls for the design of an integrated macro-fiscal policy framework that includes technology development, education reform, and radical redistribution mechanisms.

7. Conclusion and Policy Recommendations

A comment of macroeconomic history discloses that policies have generally focused on matters related to ‘’magnitude‘’ such as economic growth and price stability. The distribution of income in the economy has been considered as a phenomenon that would develop per se through development processes. Nevertheless, it is now obvious that income inequality is a notable macroeconomic problem threatening both macroeconomic stability and economic growth. Structural shocks are boosting with digitalization and the green transformation, or the Twin Transformation. Global crises have made it explicit than ever that traditional policies are no longer prevailing. Hence, it is becoming increasingly lucid that an inclusive growth model must be built and a macroeconomic reform centered on justice in income distribution must be enforced. Hence, monetary, fiscal, and income policies must be revised. Nowadays, fiscal policy remains the most powerful tool in combating inequality. Nevertheless, redistribution mechanisms based solely on taxes and transfers are insufficient on their own to address the massive wage polarization created by automation and digitalization. Hereof, Rodrik and Stantcheva (2021) recommend

that the state should prepare a ‘’pre-distribution ‘’ plans to correct pre-market inequalities before intervening in market outcomes. This requires investment in education and R&D to retrain the routine workforce excluded by technological transformation. Besides, income policies should be adjusted to prevent carbon taxes from negatively influencing lower income groups. A ‘’carbon dividend‘’ could be implemented for lower income groups. Central banks should also take notice these factors in their monetary policies, as inflation targeting regimes often disregard full employment and income inequality. This gets a factor that deepens inequality during times of crisis. Macro prudential policies should prohibit credit expansion from flowing solely to capitalists and should also be guiding in a way that supports productive SMEs and green initiatives.

Eventually, faultless macroeconomic policies are not competent for sustainable and inclusive growth. The quality of the institutions implementing them is also pivotal. Principally in developing countries, transitioning to an inclusive development model requires strong, transparent, and inclusive institutional reforms. Nevertheless, the most major component often overlooked is the cyclical timing of structural reforms. Structural reforms aimed at making the labor market more flexible, executing carbon taxes, or shifting public incentives to green industries, if implemented during recessions or crises, exponentially increase income inequality. IMF survey (2020) reveals that the costs of macroeconomic reforms are moved onto lower income groups during periods of contraction. Hence, reforms prepared for the Twin Transformation should be executed during phases of economic expansion and meanwhile supported by robust social safety nets. Besides, the state's tax capacity should be enlarged to make certain the successful implementation of these reforms (Zucman, 2015). In emerging market economies, diminishing the informal sector is not just a matter of tax auditing, it is also a matter of making certain legal protections and the right to unionize for labor. In summation, diminishing inequality and making growth inclusive are prerequisites for economic stability. To widen the reach of the Twin Transformation's opportunities and share its costs fairly, institutional government capacity requires to be rebuilt with an ‘’entrepreneurial and inclusive‘’ vision.

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Monetary Policy and Income Inequality in Türkiye: A Comparative Examination of Pasinetti Index to Gini Coefficient

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ABSTRACT

This study examines the impact of interest rate decisions on income inequality in Türkiye, a country that frequently resorts to monetary policy to achieve inclusive growth without compromising price stability. In this context, the Pasinetti Index, which is derived from the Pasinetti Rule and grounded in structural growth dynamics, and a significant measure of distributive justice, is calculated for Türkiye for the period 1978-2024. To prevent disparities between income groups, the deviation of the realized interest rate from the normative interest rate is measured, and the distributional effects of interest rate decisions are identified. The trend of the index values obtained over the years is examined comparatively with Gini coefficients, a measure of income distribution inequality. The findings provide important analytical clues that the convergence or divergence between the two indicators is influenced by structural components such as inflation, fiscal policy, and external factors, beyond the mere interest-wage dynamic of income distribution.

Keywords: Monetary Policy, Income Inequality, Pasinetti Index, Gini Coefficient, Türkiye.

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1. Introduction

While countries pursue job-creating economic growth, they also aim for a fair distribution of the generated income in society without sacrificing price stability. Although the goal is a Pareto-optimal solution, the increasing inequalities in income distribution over many years appear to be the opportunity cost of economic growth and price stability. Since countries frequently resort to monetary policy, which has lower policy lag, to promote job-creating economic growth, the impact of monetary policy on macroeconomic stability has long been of interest to academia. Nevertheless, interest in the distributional effects of monetary policy, although prominently shown by post-Keynesians, only increased towards the end of the 20th century. Until the 2008 global economic crisis, studies on the macroeconomic effects of traditional monetary policies increased, followed by studies on unconventional monetary policies. The conclusions of Rajan (2010) and Berg et al. (2018) on how inequalities can destabilize economic growth, along with Piketty's (2014) groundbreaking work, have highlighted the growing inequality in income distribution. The "World Inequality Report 2026" (WID, 2026) shows that, despite increased production and labor productivity due to technological advancements, labor's contribution is being exploited, and it reveals the extent of global income and wealth inequality. The report highlights the scale of inequality by stating that the total income earned by the top 10% income group of the world's population exceeds that of the remaining 90%, and that this top 10% owns approximately ¾ of global wealth.

This study aims to examine the impact of central bank monetary policy on income distribution in Türkiye, a country experiencing high unemployment, inflation, and income inequality during its development. To this end, the effect of interest rate decisions on income distribution in Türkiye is examined within a post-Keynesian framework, with a focus on the Pasinetti Rule. Following an introduction outlining the study's purpose, importance, and scope, the theoretical framework of the Pasinetti Rule is explained, focusing on the relationship between monetary policy and income distribution, and the empirical literature is summarized. The fourth section calculates the Pasinetti Index for Türkiye over the years and compares it with the resulting Gini coefficients. The conclusion presents policy recommendations to improve the impact of monetary policy on income distribution in Türkiye based on the findings.

2. Theoretical Framework

The distributional effects of monetary policy, while not a new area of study, date back to Keynes's "*A Tract on Monetary Reform*" in 1923 and his explanation of "rentier euthanasia" in his "*General Theory*" (1936). According to the post-Keynesian school of economics, while market dynamics and institutional structures largely influence the distribution of income in market economies, interest rate policies also play a role through various channels. In addition to Robinson's (1937) emphasis on how lowering the interest rate to zero could eliminate the fundamental problems of capitalism, Niggle (1989) states that changes in interest rate levels can affect personal income distribution through three mechanisms: causing capital losses and gains through changes in the market values of financial assets; affecting investment, employment, aggregate demand, and income; and consequently influencing income distribution and personal income distribution.

Moore (1989) added to these mechanisms the fact that interest rate policies can also affect firms' profit margins; the effect is also the sensitivity of firms' profit margins to changes in interest rates. Michl (1991) also explains that countries' borrowing interest rates cause income redistribution; therefore, changes in interest rates also change income distribution. Argitis and Pitelis (2001) also state that, all other factors remaining constant, due to cost increases caused by rising interest rates, non-wage income can shift from industrial capital to financial capital, leading to a decrease in industrial profits and, therefore, a decrease in production, thereby affecting inter-class income distribution. Many post-Keynesian economists (Lavoie and Seccareccia, 1988; Rochon and Setterfield, 2007, 2008, 2012; Seccareccia and Lavoie, 2016; Nah, 2017; Seccareccia, 2017, 2019; Qanas, 2020; Kappes et. all, 2023; Levy-Orlik and Bustamante, 2023; Seccareccia and Matamoros, 2023a, 2023b; Kappes and Rochon, 2025; Tada and Kurose, 2024; Lavoie and Seccareccia, 2025; Nalin et. all, 2025) have emphasized that interest rate policies affect income distribution among active earning groups such as workers, rentiers, and entrepreneurs (Kappes et. all, 2023).

In the post-Keynesian literature, there are three distinct "fair interest rate rules" that evaluate monetary policy from an income-distribution perspective. These are the Kasas City Rule, Smith's Rule, and Pasinetti's Rule. All three rules acknowledge that the interest rate is not neutral with respect to the distribution of financial intermediation and is a policy variable that directly shapes income distribution. The Kansas City Rule focuses on short-term redistribution goals by suggesting that the nominal interest rate be set at zero. Smith's Rule suggests setting the real interest rate at a small positive value near zero. The Pasinetti Rule,

based on structural growth dynamics, links the real interest rate to the long-term rate of productivity growth, providing a meaningful and observable measure of savings-investment compatibility and distributive equity (Rochon and Setterfield, 2007).

Luigi Pasinetti (1962), one of the leading representatives of post-Keynesian economics, reconstructed the Cambridge growth and distribution models within the framework of interclass savings; he emphasized that the saving behavior of capitalists, rather than labor income, is the primary determinant of the long-term equilibrium profit rate. Pasinetti's theoretical framework is not limited to growth theory; it also includes a normative structure applicable to the design of monetary policy. This structure, which he calls the "natural interest rate," is defined as "each creditor will receive at the end of the term, in terms of labor, a purchasing power exactly equal to the amount initially lent" (Pasinetti, 1981). Initially developed for a pure labor economy, this normative interest rate has been adapted to a general production situation (Pasinetti, 1981; Lavoie and Seccareccia, 2019, 2025). Pasinetti (2002) argues that the natural interest rate can be applied to all economic systems, both in the past and present, regardless of whether it is variable or the rate of change, and also regardless of the stability of the price level and the form of market organization. This structure, known as the Pasinetti Rule, establishes a value that does not alter the income distribution between debtors and creditors in an economy and is called the "fair/natural interest rate." This rule, by aligning the real interest rate with the rate of increase in labor productivity in the long run, lenders' purchasing power in terms of labor time is preserved, while at the same time preventing a disproportionate financial burden on borrowers (Pasinetti, 1981; Kappes, 2021; Kappes and Rochon, 2025). In short, the Pasinetti Rule states that, to maintain the purchasing power of lenders and borrowers in terms of labor time over time, the real interest rate must equal either the growth rate of labor productivity or the growth rate of real wages. In short, the Pasinetti Rule argues that, in order to keep the purchasing power of lenders and borrowers constant over time in terms of labor time, the real interest rate must be equal to either the growth rate of labor productivity or the growth rate of real wages (Seccareccia and Lavoie, 1989; Rochon and Setterfield, 2007; Lavoie and Seccareccia, 2019, 2025). This rule states that if money equivalent to one hour of labor is lent at the nominal interest rate, the total amount of principal and interest repayments will again be equivalent to one hour of labor (Kappes et. all, 2023: 8). This condition will hold as long as the share of wages remains constant; however, since real wages do not increase at the same rate as labor productivity, i.e., the share of wages mostly decreases, a "fair interest rate" equal to the growth rate of real wages has been developed. In this case, the Pasinetti Rule best reflects the

relationship between the real (nominal) interest rate and the growth rate of real (nominal) wages (Pasinetti, 2002; Lavoie and Seccareccia, 2025). Since wages and prices change in monetary units, the growth rate of real wages is taken into account when determining the interest rate that will keep the income distribution between borrowers and lenders constant in terms of labor time (Kappes et. all, 2023: 7). According to this definition, the rule is formally expressed in equation (1):

$$r^* = g_w \quad (1)$$

Here, *r** represents the normative real interest rate; gw represents the rate of increase of real wages (w/P).

This normative expression stipulates that the interest rate should be determined so as not to hinder growth, and that the income distribution between labor and capital should remain in equilibrium. Thus, establishing a clear and measurable bridge between long-term growth dynamics and monetary policy decisions enables evaluation of the distributional consequences of monetary authorities' interest-rate policies (Pasinetti, 1981; Kappes and Rochon, 2025). To examine the effects of monetary policy on income distribution, the Pasinetti Index (PI), derived from the natural/fair interest rate by post-Keynesian economists, is used. This index, which shows whether income distribution is fair in terms of labor contribution in production processes, is expressed in equation (2) (Tada and Kurose, 2024: 14):

$$PI = i_M - \sigma_M - \sigma_W \quad (2)$$

Here, *iM* represents the nominal interest rate; *σM* represents the inflation rate, and *σW* represents the real wage growth rate. We can also obtain the index by subtracting the real wage growth rate from the real interest rate (iM – σM). If the real interest rate is greater than the real wage growth rate (iM – σM > σW), income distribution favors creditors; otherwise (iM – σM < σW), income distribution favors debtors. Furthermore, a high real interest rate is associated with increasing income inequality and decreasing capital utilization, as seen in the Gini coefficient, indicating that monetary policy supports the rentier class (Tada and Kurose, 2024: 14). Kappes et. all (2023) also state that positive values of the index may indicate economic stagnation and increasing unemployment.

3. Relevant Empirical Literature

The first empirical study examining the distributional effects of monetary policy, using the Pasinetti Index, was conducted by Lavoie and Seccareccia (1988) for Canada. They systematically explained how the decrease in investment and consumption, and consequently in demand, due to rising interest rates could affect employment levels, using an index they created based on Pasinetti's work. They demonstrated how the increase in rentier share during periods of rising interest rates affected unemployment.

Seccareccia and Lavoie (2016) examined the impact of monetary policy during recessions in the US and Canada, using the Pasinetti Index to analyze income distribution between 1926 and 2013. They found similar relationships between the countries' growth and unemployment rates and the index's movements. They concluded that during periods when the index is positive, the net transfer of income favors rentiers and is associated with negative macroeconomic performance.

Nah (2017), in calculating the Pasinetti Index for South Korea for the period 1994-2015, identified a redistribution effect in favor of rentiers due to the monetary policy implemented during the deepening financialization process in the 2000s. Seccareccia (2019) examined movements in the Pasinetti Index for G7 countries over 1971-2017, noting that income was redistributed in favor of rentiers until 2008 and that the average unemployment rate remained relatively high. During periods of low interest rates and fiscal expansion, the decline in the labor force share slowed and stabilized, and the unemployment rate decreased across North America. Levy-Orlik and Bustamante (2023), using the Pasinetti Index for the period 1950-2018, found an inverse relationship between changes in the real interest rate and real wage growth in Latin American countries such as Brazil, Chile, Colombia, and Mexico. During the period of liberalization and financial globalization, the index trend indicates that the surplus value of interest rates is transferred to the financial sector.

Seccareccia and Matamoros (2023a) examined the distributional effects of monetary policies in developed countries using the Pasinetti Index; they revealed that rentier losses in the ten-year period following the global economic crisis were offset primarily by increases in business profits.

Seccareccia and Matamoros (2023b) examine the impact of monetary policy on income distribution in the 1970s and beyond. While negative Pasinetti Index values and low interest income shares calculated in the 1970s indicate a redistribution of income towards non-rent groups, it has been shown that income

was redistributed towards rent groups with the tight monetary policies implemented from the 1980s until the global financial crisis. The PI values very close to zero calculated for the post-global-crisis period indicate a constant or slightly decreasing interest income share, in other words, that the redistribution of income is towards non-rent classes. Tada and Kurose (2024) examined the impact of unconventional monetary policy practices in Japan, such as zero and negative interest rates and quantitative easing, using the Pasinetti Index. During periods of low or negative interest rates, the Pasinetti Index falls below 1, indicating suppression of rentier incomes. However, they also highlighted that a redistribution effect can be observed during periods of quantitative easing, driven by rising asset prices. Furthermore, they emphasized that when real wages or productivity remain stagnant, a normative interest rate close to zero can restrict the maneuvering room of central banking in its pursuit of price stability.

Kappes et. all (2023), using the Pasinetti Index series calculated for the period 1968-2022 in the US, examined the link between income distribution and aggregate demand using a Vector Autoregressive (VAR) model. Their findings indicate that during a stable but volatile Keynesian period, monetary policy was used to protect the income and wealth of rentiers. This reflects how this situation negatively affects aggregate demand and income distribution.

Lavoie and Seccareccia (2025) constructed the Pasinetti Index for the US and Canada by using long-term rather than banks' short-term interest rates. It was found that while the wage/profit relationship, which is a factor share, remains stable, the Pasinetti Index calculated based on labor productivity and the Pasinetti Index based on wage increases follow a similar trend. When labor costs diverge from the average increase in labor productivity, the two series generally move together. This finding suggests that interest rate decisions made within the monetary policy framework dominate income transfer, as measured by both series. For Latin American countries, the Pasinetti Index, which examines how interest rate shocks affected income shares within an integrated macroeconomic structure during the 1950-1980 period, both in terms of productivity and wage growth, was also studied by Nalin et. all (2025); the series were found to be relatively congruent and close to equilibrium. During the post-1980 debt crisis, it was shown that the high real interest rate policy pushed the index above 1, causing a negative impact on labor income in the redistribution of income.

In general, post-Keynesian analyses conclude that net income transfers in favor of rentiers are associated with adverse macroeconomic performance. The empirical evidence examined shows that the Pasinetti Index is a powerful and reliable tool for tracking the impact of monetary policy on income distribution.

Furthermore, when calculating the index for both developed and developing economies, whether considering growth in labor productivity or wage growth, the results generally exhibit similar trends. In this context, depending on the available data for the country under consideration, a productivity or wage-based index can be calculated. Since no studies on the Pasinetti Index for Türkiye were found in the relevant literature review, Türkiye constitutes the subject of this study.

4. Methodology, Comparative Examination And Findings

In this section, the Pasinetti Index is calculated for the Turkish economy over a 47-year period from 1978 to 2024. The obtained index values are analyzed in comparison with the country's Gini coefficient year by year. Based on the findings, the impact of interest rate policies implemented in Türkiye on income distribution is revealed.

4.1. Data and Methodology

The description of the data used in this study and the sources from which it has been obtained are presented in Table 1.

Table 1. Data Set Description

Variable	Defination	Source
Nominal Deposit Interest Rate (%)	It is the weighted average of the interest rates that commercial banks apply to short-term demand and time deposits.	The World Bank, World Development Indicators (WDI), 2026a.
Inflation Rate (%)	It is the percentage change in the Consumer Price Index compared to the previous year.	The World Bank, World Development Indicators (WDI), 2026a.
Nominal Minimum Wage	This is the year-end value of the gross monthly minimum wage (TL/month) applicable to those aged 16 and older for each calendar year.	Republic of Türkiye Ministry of Labour and Social Security, General Directorate of Labor, Labor Life Statistics, Annual and Monthly Salaries by Year, 2026.
Gini Coefficient	It is an indicator of income inequality. Purchasing Power Parity (PPPs), 2021.	The World Bank, Poverty & Inequality Platform, 2026b.

Instead of using the CBRT policy rate or Treasury bond interest rate to represent the interest rate, the deposit interest rate, which reflects monetary policy to a broad segment of savers, has been preferred. This has enabled the creation of a long-term time series spanning 47 years. Real deposit interest rates have been obtained by deflating nominal deposit interest rates using inflation rates over the years.

Instead of the labor productivity variable, the labor wage variable has been chosen to account for changes in wages and prices in Türkiye, which suffers from persistently high inflation. This choice has also been influenced by the fact that more than 50% of wage earners in Türkiye receive the minimum wage. With the monetary reform of January 1, 2005, 1 New Turkish Lira was equated to 1,000,000 Old Turkish Lira. All nominal wage values prior to 2005 were converted to the new Turkish Lira. The nominal minimum wage has been adjusted for inflation, and the growth rate has been calculated.

Gini coefficients have been obtained as a continuous series from 2002 onwards. Within these constraints, the starting year of the analysis was set to the first data year with nominal deposit interest rate data, and the ending year to the last available data year. After adjustments to the data, the Pasinetti Index was calculated using equation (3) (Lavoie and Seccareccia, 2024; Kappes and Rochon, 2025):

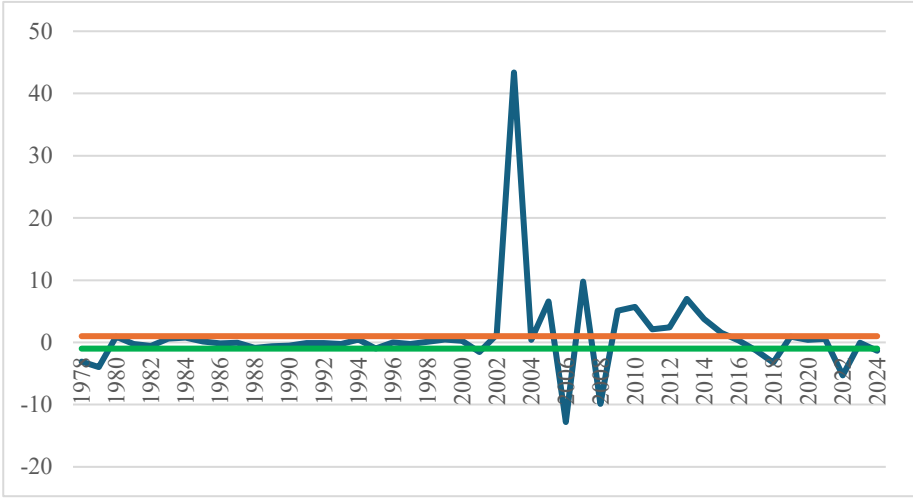
$$PI_t = \frac{r_t}{g_{W,t}} \tag{3}$$

Here, r_t represents the real interest rate, and $g_{W,t}$ represents the growth in labor productivity. In periods when $PI_t > 1$, it indicates a significant divergence between the worker and rentier classes. However, understanding the direction and channel of this divergence is possible only by evaluating the mathematical sign and magnitude of the incomes of the two classes together. According to this calculation developed by Lavoie and Seccareccia (2024) and Kappes and Rochon (2025), when both r_t and $g_{W,t}$ are positive, $PI_t > 0$ is obtained. This result indicates that both income groups are gaining; however, if $PI_t > 1$, it shows a distribution in favor of rentier income. When both r_t and $g_{W,t}$ are negative, $PI_t > 0$ is obtained. This indicates that both income groups are losing. Very high PI_t values also point to methodological limitations. When one of the r_t and $g_{W,t}$ series takes a positive value, and the other takes a negative value, $PI_t < 0$ gives a result, while at the same time, if $PI_t < 1$, it is determined that there is a redistribution in favor of whichever variable is positive.

4.2. Comparative Examination and Findings

The trend of the Pasinetti Index for Türkiye, calculated for the period 1978-2024, is presented in Graph 1. In the graph, the +1 and -1 levels indicate the thresholds at which income groups diverge significantly.

Graph 1. Trend of the Pasinetti Index in Türkiye (1978-2024)



Source: Generated from the author's calculations.

During the 1978–1980 period in Türkiye, which was struggling with chronic currency crises, budget deficits, and political instability, real interest rates turned negative due to high inflation relative to fixed nominal interest rates, leading to a redistribution of income from depositors to borrowers. While depositors lost, the erosion of wages due to high inflation was offset by the increase in nominal wages; the Pasinetti Index, which is in the -3/-4 band, indicates that monetary policy favored wage earners. The high inflation experienced in 1980 caused both the erosion of the fixed minimum wage and negative real interest rates, resulting in a decrease in earnings for both wage earners and rentiers. Therefore, although the index is positive, it is calculated close to the technical interpretation limit at 0.92.

(Source: Produced from the author's calculations.) Following the 1980 military intervention and the January 24th decrees, the Pasinetti Index never exceeded +/-1 in any year from the beginning of the financial liberalization period in Türkiye until 2001. This shows that the Pasinetti Index, which "measures the extent to

which actual interest rates deviate from the normative interest rate" (Kappes and Rochon, 2025), did not remain proportional to the deviation. This period was one in which pressure on the financial sector persisted, and both depositors and wage earners lost out to inflation.

Despite the liberalization of the capital account and the high-interest-rate policies pursued from 1989 onwards to attract short-term capital, high inflation reduced the earnings of the rentier class. Although the index, which showed a negative trend due to the increase in the real minimum wage, did not exceed 1, it indicates that the policies pursued until 1994 resulted in a favorable outcome for wage earners.

In 1994, a crisis year when inflation and interest rates reached triple digits, the decrease in real wages and interest rates eroded incomes for both groups; this effect resulted in the index taking a positive value of 0.46. During the 1995-1998 period, when inflation became chronic, income declined among the rentier class, largely due to negative real interest rates, while the strong nominal increases in the minimum wage favored wage earners, as confirmed by the index. However, in 1998, the approximately 27% erosion of real wages, along with a decrease in rentier incomes, caused the Pasinetti Index to take a positive but near-zero value. The index similarly reached 0.44 in 1999, but as inflation declined that year, real interest rates and real wages increased in tandem.

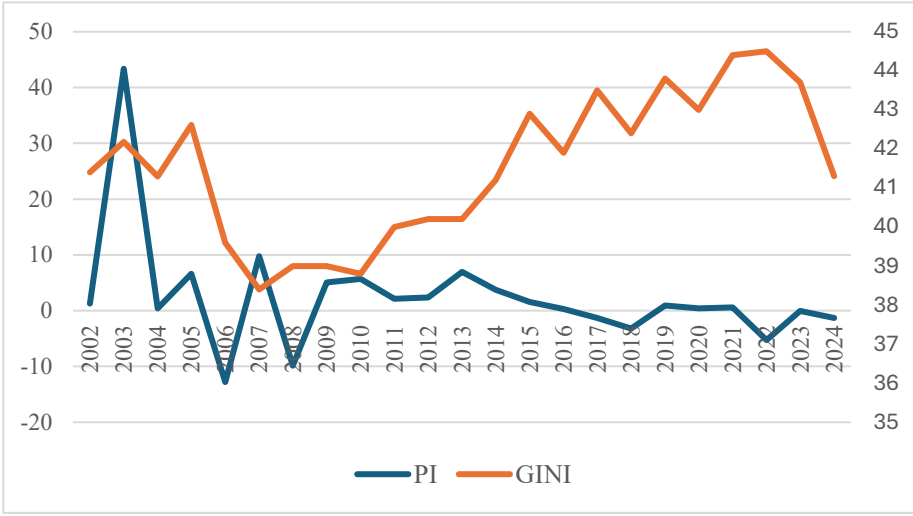
During the 2000–2007 period, when Türkiye curbed chronic inflation with an IMF-backed stabilization program, the crises of November 2000 and February 2001 caused nominal interest rates to exceed inflation, leading to increased real interest rates and consequently, income growth for the rentier class. The erosion of real wages due to inflation resulted in the index reaching values of 1.56 and -12.8 in 2001 and 2006, respectively, indicating a significant divergence between sectors. 2003 was the year this divergence peaked. The decline of inflation to single digits, coupled with a significant increase in real interest rates and near-zero real wage growth, caused the Pasinetti Index to reach an extreme value of 43.37. This reflects the absolute superiority of rentier income over wage income; however, the index's extremely small denominator, representing real wage growth, makes interpreting its value difficult. Although not as pronounced as in 2003, the Pasinetti Index in 2005 and 2007 also shows that the high-interest-rate policies of the time had a rentier-favorable effect on income distribution across sectors.

The 9.86 contraction in the index due to the 2008 global economic crisis indicates a distribution that developed against wage earners. The high real interest rates and limited minimum wage increases during the 2008-2015 period mostly indicate

that the index remained above 2, pointing to the systematic superiority of financial returns over labor income. With the 2016 increase in the minimum wage, aimed at compensating for the widening income gap between sectors, real wage growth reached its highest level in the 47-year time series.

The rise in real interest rates in 2017-2018, despite the erosion of real wages due to rising inflation and the currency crisis, confirms the widening disparity between income groups, as evidenced by the steadily rising index value. Between 2019 and 2021, the index approached equilibrium, or 0, as real deposit interest rates neared zero and minimum wage increases lagged behind inflation. The expansionary policies pursued during the pandemic prevented the deepening of structural inequalities; however, they persisted. In 2020, during the pandemic, the real deposit interest rate fell to 0.96%; real wage growth remained marginally positive at 2.45%; PI = 0.39. The Gini coefficient remained relatively stable in the 43.0-44.4 range; this stability, while consistent with PI values in the equilibrium region, indicates the persistence of structural inequality. In 2022, when expansionary policies peaked, the developing hyperinflation and the deepest negative real interest rate experienced led to a decrease in rentier incomes. Although there was a limited real increase in the minimum wage during this period, the Pasinetti Index fell to -5.28. Undoubtedly, the reason for this significant divergence between segments is hyperinflation. While the implementation of high policy interest rates to combat inflation turned the real interest rate positive, real wages decreased because inflation remained high. The return to orthodox monetary policy, while saving financial savings, could not prevent the erosion of the purchasing power of low-income workers. The combined assessment of the Pasinetti Index, which shows the distributional effect of monetary policy, and the Gini coefficient, which measures income inequality, is important for validating the findings. Therefore, the combined trend of these two indicators over the years is shown in Graph 2.

Graph 2. Trend of Pasinetti Index and Gini Coefficient in Türkiye (2002-2024)



Source: The Pasinetti Index was generated using the author's calculations, while the Gini Coefficient was produced using data from The World Bank, Poverty & Inequality Platform (2026b).

Graph 2 provides a concrete example that there is not necessarily a linear relationship between the Pasinetti Index and the Gini coefficient. During the period examined, the index was highly volatile, while the Gini coefficient trended towards equality. When the index exceeds equilibrium (> +/- 1), the upward trend in the Gini coefficient confirms increasing inequality, and the downward trend confirms increasing inequality. In 2003, the unusual index value, driven by the rise in nominal deposit interest rates and the extremely low levels of real wage growth, increased the purchasing power of the rentier class much faster than that of wage earners. This trend reversed in 2006 due to negative real interest rates and increases in the real minimum wage. The Gini coefficient also showed a downward trend, confirming this divergence.

Despite the index indicating increased inequality due to expansionary policies such as interest rate cuts, transfer payments, unemployment benefits, and strong real increases in the minimum wage, implemented to compensate for the contraction caused by the 2008 global economic crisis, the Gini coefficient remained stable. The 2008-2016 period reveals that Türkiye, within its relatively stable interest-wage balance, carried significant inequality pressure. While the index consistently exceeded equilibrium, the net increase in the Gini coefficient at the end of the period suggests a deepening structural gap between wage income

and capital income. The 2017-2024 period contains the most striking transformations for both indicators. From 2017 onwards, the erosion of real deposit returns, due to hyperinflation and real minimum wage increases, indicates a favorable effect for wage earners; however, the Gini coefficient trended upward into the 42-44 range during this period, indicating increasing inequality. The fundamental reason for this paradoxical trend is that hyperinflation erodes purchasing power unevenly among household income groups. Low-income households face higher inflation in basic consumer goods such as food, energy, and rent, and since nominal minimum wage increases cannot truly offset this inflation, the gap between income groups widens. It is also understood that income distribution inertia and structural inequality dynamics proved far more resilient than periodic changes in interest rates and wages during the 2019-2021 period. In 2022, inflation disproportionately eroded the budgets of low-income households by increasing the cost of basic consumer goods. At the same time, while real asset holders protected their purchasing power through access to hedging instruments such as foreign currency, gold, and real estate, deposit interest rates lagged far behind inflation, negatively impacting middle-income groups with low savings. In short, inflation harmed both depositors and low-wage earners; however, because these channels of harm differed, the index and the Gini coefficient showed worsening but divergent effects. In a hyperinflationary environment, the negative index does not stem from an acquired labor advantage but from a significant erosion of real deposit returns, which perfectly aligns with the deterioration in the Gini coefficient. Following the Central Bank's initiation of monetary tightening to curb hyperinflation in 2023, despite the gradual recovery of real deposit interest rates and adjustments to the minimum wage, we can say that the ongoing high inflation has created a distributional effect on wage earners. This conclusion is confirmed by the trend in the Pasinetti Index. According to the Turkish Statistical Institute, Income Distribution Statistics (2025), the Gini coefficient, announced as 41 for 2025, indicates a decreasing trend in income inequality.

5. Concluding Remarks

This study examines the impact of interest rate adjustments, a frequently used monetary policy tool in combating economic problems such as recession, unemployment, inflation, and current account deficits in Türkiye over a 47-year period, on income distribution in the country. This examination is based on the Pasinetti Rule within a post-Keynesian approach. This rule argues that for real interest rates to be linked to labor productivity or real wage growth, there should be no disparity between income groups in an economy. The Pasinetti Index,

derived from this rule, measures the degree and channel of deviation of the actual real interest rate from its desired level.

The index values calculated for the period 1978-2024 confirm the experience of income inequality between classes in Türkiye, influenced by economic problems, crises, and the pandemic. It can be said that interest rate increases pursued to combat inflation have created distributional effects favoring rentiers, while expansionary policies have created distributional effects favoring wage earners. The Pasinetti Index identifies the direction and magnitude of the interest rate-wage gap with considerable accuracy; however, it is not sufficient on its own to determine the actual course of inequality. Therefore, evaluating the index alongside Gini coefficients, a measure of income distribution inequality, is important for determining whether the distribution of income shares has become actual inequality in the country. For this reason, the trend in index values over the years is examined comparatively with Gini coefficients. The findings clearly show that the dynamics of income distribution in Türkiye are not limited to the gap between income shares, such as interest and wages. The convergence or divergence between these two indicators can stem from various factors. In particular, the effects of increased employment, expansionary fiscal policies, and increases in disposable income resulting from gratuitous transfers during periods of accelerated economic growth can suppress redistribution against wage earners. In addition, the heterogeneous effects of inflation across income groups can widen the gap in income shares. Preferences for foreign currencies and for movable and immovable assets may also arise to avoid the income-erosion effect of inflation. The fact that this perspective is not taken into account in the Pasinetti Index, and that only income shares such as interest and wages are taken as the basis, leads to a partial omission of the impact of interest rate decisions on income distribution. Therefore, it is recommended that the index be expanded in future research to include factors such as ownership structure, fiscal policy, and investment preferences, in addition to income share dynamics

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Beyond Inflation Targeting: Rethinking Monetary Policy in the Era of Climate Risk Concerns

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Abstract

Climate change has introduced structural changes that have rendered many traditional macroeconomic models obsolete. A major concern is how monetary policy should respond to the new economic realities posed by climate change, beyond the central banks' exclusive focus on interest rate adjustments and inflation targeting. This chapter examines paradigm shifts in monetary policy over the past 30 years and explains why the new era of monetary policy must prioritize climate sustainability. Relying on the statistics from eight countries: Australia, Canada, China, India, Japan, Switzerland, the United Kingdom, and the United States, the study argues that inflation rates were effectively managed during the inflation-targeting monetary policy regime, but climate risk concerns were minimal with green bond market largely underdeveloped. Monetary rates generally declined during the post-GFC period as average inflation rates remained low, but average carbon emissions and climate concerns increased. Furthermore, green bonds were introduced, reflecting the integration of climate-related finance into central bank policy discussions. The post-COVID era has been characterized by rapid growth in sustainable finance and persistent emission and climate risks. Nevertheless, significant differences remain across countries, reflecting variations in their environmental and monetary policy objectives.

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Keywords: Monetary policy framework; Inflation targeting; Exchange rates; Climate risks; Post-COVID-19 era

1. Introduction

Over the past two hundred years, the objectives of monetary policy have evolved from a narrow focus on currency stability, to an increasing interest in macroeconomic stabilization and economic growth, and the monetary policy operating frameworks have evolved from a strict adherence to the gold standard in the nineteenth century to the Keynesian framework of the active use of state interventions in the economy in the twentieth century to inflation targeting in the late twentieth and early twenty-first century to the common use of unconventional monetary policy measures (such as quantitative easing) in the wake of major economic shocks. Thus, the main feature of this evolutionary process across every stage has been that, in response to changing economic conditions and new domestic and international challenges, central banks have become ever more flexible, adaptable, and proactive in addressing a range of economic disturbances. In contrast to previous monetary regimes, characterized by the priority given to stabilizing the nominal exchange rate and the purchasing power of money, contemporary monetary policy has increasingly started to pursue other macroeconomic objectives such as price stability, promoting economic growth in a sustainable manner, generating employment and ensuring the stability of the financial system. This helps to explain the changing role of monetary policy frameworks.

Conventional monetary policy has generally provided central banks with powerful tools for controlling business cycles, but the current framework for monetary policy does not fit the more complex and globalized world economy of the twenty-first century. Short term interest rates, reserve requirements, and open market operations have been important tools of monetary policy for controlling inflation, money supply, and business cycles. But recent global crises, including the Global Financial Crisis of 2008, the COVID-19 pandemic, climate change, geopolitical tensions, supply chain disruptions, and rapid technological shifts, have highlighted shortcomings of these customary approaches to monetary policy, as they suggest that macroeconomic instability is increasingly driven by structural, environmental, technological and geopolitical factors that cannot be easily addressed by monetary policy alone. At the same time, central banks are increasingly confronted with multiple risks which may require a multidimensional and coordinated response that goes beyond what has customarily been achievable through conventional monetary policy tools. These developments potentially call

for a reappraisal of the objectives, transmission mechanisms and operational frameworks of monetary policy in general.

Monetary policy and central banking today are witnessing a model shift towards a broader and more integrated economic policy framework that includes sustainability issues alongside customary macroeconomic objectives. Central banks are increasingly looking to expand their mandate beyond price stability, financial stability and the performance of operational functions to cover climate risk and environmental sustainability, digital financial services, financial inclusion and systemic resilience. Climate change is a major source of medium and long-term macroeconomic uncertainty arising from both physical risks (e.g., from extreme weather and natural disasters) and transition risks associated with a global transition to net zero carbon economies. Climate-related macroeconomic uncertainty can affect inflation, productivity, labor markets, the stability of the financial system, and long-term economic growth. Central banks have increasingly come to realize that monetary policy needs to lead the economic adjustment to climate-related shocks while still achieving its key mandates of financial stability and sustainable development. As a result, modern monetary policy has come to be seen as not just one instrument for macroeconomic stabilization, but as a system of multiple policies addressing a series of interconnected economic, financial, environmental, and technology challenges. It is thus a natural extension to explore the evolution of monetary policy frameworks over recent decades and the growing relevance of climate sustainability for policy-making.

The chapter canvasses the evolution of monetary policy frameworks in the past three decades, and explains why climate sustainability needs to be a core consideration for monetary policy in the new era. We present the statistical evidence for this finding in eight G-20 countries: Australia, Canada, China, India, Japan, Switzerland, the United Kingdom and the United States. These countries were selected because they match different monetary-policy regimes, levels of development, and degrees of coverage in terms of embedding sustainability considerations in central banking practices. Therefore, a comparison between these countries allows to capture the evolution of monetary policy and its response to sustainability challenges at the international level. The rest of this chapter will be structured as follows. Section 2 reviews the monetarist and Keynesian views of monetary policy and the intrinsic limits of both. Subsequently, section 3 looks into why these monetary policy frameworks are no longer adequate to cope with the current global environment. Section 4 discusses the consequences for monetary policy of this new model, and Section 5 reviews the changes in monetary policy in the light of the statistical experience in the eight countries.

Finally, the concluding section summarizes the main findings, discusses their policy implications, and suggests directions for future research.

2. The traditional monetary policy perspectives and their shortcomings

Classic macroeconomic frameworks were formulated at a time in which macroeconomic conditions were relatively stable, and macroeconomic shocks were less complex, more predictable and only affected aggregate demand or aggregate supply and the financial system. For example, many central banks used conventional monetary policy tools which included changes in the policy interest rate and open market operations (OMO) with government bonds to affect liquidity and economic activity (Committee on the Global Financial System, 2019). Within the confines of this customary school, rival schools of economic thought had diverged on the causes of macroeconomic instability, and on the proper role of monetary policy. Keynes (1936), for instance, argued that instability in the economic system was largely due to instability in aggregate demand, and advocated active monetary policy to stimulate investment and consumption through the manipulation of interest rates. On the other hand, Friedman (1968) stressed the role of change in the money supply in causing inflation and business cycles, and recommended a rules-based monetary policy focused on price stability. While these approaches diverged in their assumptions about monetary policy transmission channels, they were developed in a period of cyclical, financial business cycle shocks. Today, however, the macroeconomy is increasingly exposed to a set of systemic, interconnected, and persistent shocks such as climate, geopolitical fragmentation, pandemics, and technological disruption which are not well captured by customary monetary models. The current macroeconomic model for monetary policy needs to evolve. The new model must combine demand management, price stability, and unconventional policy tools to strengthen the economy's resilience to complex and systemic risks. This changing macroeconomic environment reinforces the need to gain a better understanding of how climate shocks impact monetary policy transmission channels in the economy.

In addition, climate risks give rise to supply-side shocks that are not amenable to monetary policy, as opposed to typical recessions, which have demand-side origins. There are climate-change related physical risks and transition risks that influence supply-side factors of the economy, such as potential labor productivity growth, energy costs, as well as investment decisions of firms and financial

stability (McKibbin et al. 2020; European Central Bank 2021). They stem from climate change effects on weather shocks, floods, droughts, and wildfires. Moreover, these disruptions could weaken the effectiveness of conventional monetary policy actions, since any change in policy rates would not restore lost production capacity, eliminate supply-side shortages, or undo the inflationary impacts from climate change shocks. A growing body of literature finds that climate risks are increasingly influencing inflation dynamics, key decisions on credit allocation, asset prices, and financial stability, thereby also impacting conventional transmission channels of monetary policy. As a result, central banks have begun to see climate change not just as an environmental issue but also as a macroeconomic and financial one that needs new policy frameworks to deal with supply-side structural shocks. This chapter, therefore, analyzes the relationship between climate change and supply shocks and discusses why climate change has become such a key issue for monetary policy.

2.1 Climate change and supply shock

Climate-related physical and transition shocks can affect the supply side, challenging the effectiveness of monetary policy. The effects of physical shocks may result from extreme weather events that affect labour supply, disrupt production, break supply chains, and alter trade relations, or from floods and wildfires that damage infrastructure and capital stock. Transition shocks include energy transitions and policy shifts that increase production and compliance costs, changing consumer preferences that demand technological changes, redirection of capital stock to greener production, redistribution of wealth among nations, geopolitical tensions, and geoeconomic fragmentation. Deryugina and Hsiang (2014), Moore and Diaz (2015), and Acevedo et al. (2020) provide empirical evidence on the negative impact of extreme temperatures on basic economic elements such as investment, labor productivity, and health. The consequence of a decline in these factors is reduced output. According to Fankhauser and Tol (2005), reduced output affects subsequent capital accumulation, so that future production may be reduced further as climate risk decreases optimism and delays investment, thus further reducing capital. These factors introduce long-term structural changes and uncertainty shocks that make it difficult to predict aggregate supply, future energy inflation, and potential output. Economies are now fundamentally driven by these shocks, which can sometimes be persistent. However, monetary policy is typically a short-term adjustment tool, usually spanning two to three years, and may struggle to address the impact of climate risks that unfold over decades. Traditional tools or inflation-targeting frameworks

may not be sufficient because the relationships between climate change and the current macroeconomic landscape are no longer as stable as previously assumed.

2.2 Climate change and demand shock

On the demand side, transition risk involves changing consumer preferences, which are now shaping market supply, relative prices, and trade competitiveness. Physical risk alters consumption patterns as societies may prioritize reconstruction and resettlement after severe damage. This can make it more difficult to predict economic outcomes, especially where the effects are irreversible. Such uncertainty can increase climate-related uncertainty, delaying investments (Acevedo et al., 2020). Similarly, low demand for products could lead to low demand for labour, putting downward pressure on wages. The persistence of this over time may cause challenges for price stability as labour and commodity market prices deviate from the monetary policy target. Empirical studies have confirmed that climate change concerns are relevant for monetary policy because of their impact on price stability. Mukherjee and Ouattara (2021) confirmed that climate change is a threat to monetary policy after finding a persistent impact of climate change on inflation in a panel analysis of 107 countries using a panel-VAR method. The impact in developing countries is of particular concern, as the effects of climate change did not ease after the initial shock. Similarly, Yalçınkaya et al. (2026) provide evidence using G-20 data showing that the persistent and unfavourable impact of climate change on price stability limits the effectiveness of monetary policy. This is particularly pronounced in developing countries due to their high vulnerability. Yalçinkaya et al. (2025) applied the Bayesian Local Projections methodology to data from the US and show that temperature shocks have persistent inflationary effects on both realized inflation and inflation expectations. Their findings also suggest that climate risk complicates the Federal Reserve's ability to stabilize prices. Natoli (2023) quantified the effects of temperature shocks on the United States economy and linked the negative impact of unfavourable temperature shocks on consumer prices, interest rates, and GDP to a slowdown in aggregate demand caused by climate shocks.

2.3 Climate risk and financial system stability

Climate risk can be transmitted to the financial system through bank balance sheets, insurance markets, and financial markets by increasing systemic risks, reducing collateral, lowering asset prices, and creating market volatility (Network for Greening the Financial System, 2019; Diluiso et al., 2021). If infrastructure is

reduced as a result of physical risks such as floods or fire, this disrupts economic activity, increases credit losses, and reduces the value of collateral, putting stress on the banking sector to reduce interest rates (Kranz et al., 2024). Similarly, if climate transition leads to stranded assets due to the rapid devaluation of assets in carbon-intensive sectors as preferences shift towards a low-carbon economy (Network for Greening the Financial System, 2019; Bolton et al., 2020), this risk causes large volatility in asset prices and creates financial market risk. However, the traditional financial system does not capture these effects, so the central bank may be forced to adopt conventional monetary policy measures to achieve macroeconomic stability. Recent developments in the empirical literature provide strong evidence that climate risk has become a source of systemic financial risk. For example, Jia and Du (2024) examined the impact of climate change on 112 Chinese financial-sector companies and found high systemic financial risk due to extreme temperatures. Diluiso et al. (2021) also found that transition risk increases inflation volatility with climate policy uncertainty, necessitating a strong monetary policy. Comerford and Spiganti (2023) confirmed that carbon bubbles can trigger instabilities due to asset write-offs, but targeted policy intervention can safeguard investors' balance sheets against adverse effects. Liu et al. (2024) examined the impact of climate risk on financial stability in 53 countries and showed that climate risk adversely affects financial stability, but the severity depends on the level of financial and economic development in each country. While green quantitative easing may cushion the severe effects of financial shocks during transition, its stabilizing properties remain insufficient. These studies justify the need for climate-oriented monetary policies, such as climate stress testing and green refinancing programs, to reduce vulnerabilities in financial stability.

2.4 Climate risk and exchange-rate dynamics

Since climate shocks can affect the stability of the financial system and trade balances, there may be potential asset devaluations if central bank balance sheets are significantly affected. Therefore, climate risk is transmitted through a nation's current and capital accounts to the exchange rate. Climate physical risk is transmitted to the exchange rate market through reduced total factor productivity and exports due to extreme weather, leading to negative trade balances (Yahya et al., 2025). Through transition risk, there is a loss of competitiveness in carbon-intensive sectors, and if this dominates the productive sector, it can decrease capital inflows and increase capital outflows as foreign investors reallocate capital to sustainability sectors. This will weaken domestic currencies and can increase

exchange rate volatility if risk perception is higher (Liu et al., 2024). Ma et al. (2025) provide evidence by assessing the effects of climate physical risk on 77 currencies. Their study shows that most currencies, especially those of developing economies and currencies under floating exchange rate regimes, depreciated in response to climate shocks. Empirical evidence also indicates that climate vulnerability can weaken central banks' resilience and force policymakers to devote greater attention to exchange rate stabilization, reducing policy flexibility. This was confirmed by Yahya et al. (2025), who investigated central banks' resilience to climate risks in a panel of 115 countries. They also observed that climate risk reduces the operational flexibility of central banks and forces them to prioritize exchange rate stabilization, which further limits their flexibility, especially in cases of weak financial and public systems and in countries experiencing higher output volatility. However, green policies and financial openness acted as mediators that reduce the negative impact of climate risk on central banks' policy effectiveness (Yahya et al., 2025). According to Bolton et al. (2020), climate shocks bypass the traditional mechanisms of interest rate transmission, while conventional monetary policy can only influence exchange rates through interest rate differentials. Therefore, it cannot directly address exchange rate fluctuations introduced by climate-related events.

3. Why existing paradigms are insufficient

Macroeconomic conditions have become less predictable than in the past. Managing long-term supply and demand shocks, financial instability, and environmental externalities arising from climate risk requires a broader monetary policy framework that integrates monetary, financial, and environmental objectives. Since conventional monetary policy was designed to manage short-term demand fluctuations, achieve price stability, promote economic growth, and stabilize employment, it struggles to address emerging sources of macroeconomic uncertainty associated with climate risk. This includes changing macroeconomic patterns, shifting trade patterns, capital reallocation, and long-term structural transformations as discussed above. Consistent with Keynesian economics, traditional monetary policy is most effective at managing demand-driven instabilities because it can moderate pressures induced by aggregate demand (Keynes, 1936). However, climate risk often generates supply-side shocks, resulting in climate-related inflation and, at times, stagflation, as these shocks can simultaneously increase inflation and reduce output. Hauzenberger et al. (2021) explain that central banks' transmission channels are impaired during periods of high uncertainty, making conventional monetary policy less effective. Therefore,

relying solely on conventional interest rate adjustments may be ineffective. Monetary policy may aim to reduce demand through contractionary measures, but it cannot prevent droughts, floods, heatwaves, or resource shortages caused by climate change. A major development in the new era of monetary policy is the recognition that climate risk is a significant source of inflationary pressures, operating through both demand and supply channels, and a major source of financial instability, affecting banks' balance sheets. Certain reasons account for this.

3.1 Market neutrality versus green tilting

Traditional monetary policy emphasises central banks' neutrality and independence. However, quantitative easing may reflect existing market preferences for carbon-intensive sectors, limiting central banks' influence (European Central Bank, 2021; Network for Greening the Financial System, 2021). Although this market neutrality has been defended as a means of preserving central banks' independence, it can amplify the macroeconomic impacts of negative externalities and diminish the effects of positive externalities in the long term (Braga et al., 2025). This suggests that central banks' neutrality may provide financial incentives for investment in pollution-intensive industries. If policy is to favour green sectors by incorporating green bond purchases and reducing exposure to carbon-intensive assets, this would require political involvement, which conventional monetary policy does not support. Nevertheless, integrating climate considerations into monetary operations may be necessary to mitigate supply shocks caused by climate transition risk and to maintain price and financial stability during transition shocks.

3.2 The "Blunt Tool" Problem

Interest rates are generally recognized as a blunt instrument. When a central bank raises the benchmark rate, it increases the cost of borrowing for everyone across the entire economy (Sonoda & Sudo, 2015). Energy transition infrastructure requires significant capital investment, but central banks' interest rates apply to the aggregate economy without distinction. While policy may aim to lower inflation by increasing interest rates, this can unintentionally raise the capital cost of green projects, stifle investment in this sector, and consequently delay the green transition. Interest rate targeting cannot directly channel capital away from carbon-intensive sectors towards green projects. Therefore, relying on conventional monetary policy shifts from precision to generality. For these

reasons, the modern era of monetary policy, evolving into a multifaceted mechanism, allows central banks to incorporate climate risk. Without this, it is difficult to maintain macroeconomic stability under the influence of climate risk.

4. Implications for the "new era" of monetary policy

Given the limitations of traditional monetary policy, it has evolved across regimes to address contemporary challenges, as described in Table 1. The new era of monetary policy now targets macroeconomic resilience and sustainability, in addition to its financial stability objective. Therefore, monetary policy is being expanded to address climate-related risks. This has led to the inclusion of green finance and other climate considerations, such as climate stress testing of financial institutions, climate-related financial disclosures, green quantitative easing, climate-adjusted collateral frameworks, and the integration of climate risk into macroprudential regulation. Furthermore, monetary policy needs to focus on green sector-specific investment, green infrastructure financing, energy transition, and the decarbonisation agenda, rather than relying on the broad policy of using interest rates to influence the aggregate economy (Noera, 2024). Table 2 provides a comparison of the levels of climate integration into monetary policies across nine prominent central banks.

Table 1. Comparison of monetary policy focus across the different regimes

Monetary policy era	**Pre-1980**	**Pre- Global Financial Crisis 1980–2007**	**Post-2008 Global Financial Crisis 2008–2019**	**Post-COVID and Climate Era 2020–2025**
Main Focus	Economic growth and employment.	Inflation targeting and price stability.	Financial stability.	Resilience, sustainability, and financial stability.
Policy Tools	Interest rate adjustments.	Policy rates, reserve requirements.	Quantitative easing (QE), forward guidance.	QE, macroprudential policies, green finance initiatives.

Table 2. The new perspective from central banks' practices and climate integration

	Central Bank	Climate Integration	Major Initiatives	Source
1	European Central Bank	High	Climate stress testing, green asset purchases, risk assessment.	Bank of England. (2021), European Central Bank (2024),
2	Bank of England	High	Climate risk supervision, climate scenario analysis, green quantitative easing (green QE) - corporate bond purchase scheme (CBPS)	DiLeo (2023), Bank of England (2024), Holden et al., (2024), Noera (2024), and Dafermos (2026).
3	People's Bank of China	Moderate – High	Green lending programs, targeted green refinancing, green bonds collateral pools for PBOC medium-term lending facilities, macroprudential assessments.	Zhang et al. (2020) and Macaire and Naef (2023).
4	Federal Reserve	Limited	Climate monitoring, scenario analysis, stress tests, and research; however, major responsibility is delegated to elected officials	Gibson (2023) and Powell (2023).
5	The Bank of Japan (BOJ)	Limited direct monetary intervention.	Green funds facility, neutral supervision, pilot scenario analysis, stress testing.	Kranz et al. (2024).
6	Swiss National Bank (SNB)	Limited	Climate risk monitoring, exclusion policy, analytical integration.	Swiss National Bank (2024).
7	Reserve Bank of India (RBI)	High (Targeted)	Sovereign green bonds, green deposits framework, priority sector lending.	Reserve Bank of India (2024), Sanjay Malhotra (2025), and Thomas and Thangam (2026).
8	Bank of Canada (BoC)	High	Advanced economic modeling of climate-transition scenarios, strict supervisory mandate, climate-related stress testing, integration of climate risk	Bank of Canada and Office of the Superintendent of Financial Institutions (2024), and Office of the Superintendent of

			into financial stability assessments, extensive climate-related research on inflation and macroeconomic impacts.	Financial Institutions (2025).
9	Reserve Bank of Australia (RBA)	Low-Moderate	Climate risk analysis, scenario analysis, incorporates shocks into inflation dynamics.	Reserve Bank of Australia (2023).

5. Descriptive analysis of monetary policy evolution

Descriptive evidence from eight sampled countries – Australia, Canada, China, India, Japan, Switzerland, the United Kingdom, and the United States – reflects how monetary policy is becoming relevant for climate risk and vice versa. Data description, sources, and the rationale for the assessment are presented in Table 3. The average values of climate and economic indicators are computed and analysed across four different monetary policy regimes. The analysis examines changes in monetary policy conditions, climate risk exposure, carbon emissions, macroeconomic stability, economic performance, external stability, and sustainable finance development across the four eras. The computed mean values are presented for each country in Tables 4–12.

Table 3. Data description and sources

Dimension	Indicator	Measurement	Source	Rationale
Monetary Policy	Average Central Bank Policy Rate	%	Bank for International Settlements (2026).	Indicates monetary policy stance across different regimes.
Climate Risk	Climate Physical Risk Index	Units	IMF Climate Change Indicators database.	Measures exposure to climate hazards.
Carbon Footprint	CO_2Emissions	Mt CO_2e	WDI.	Indicates contribution to greenhouse gas emissions.

Macroeconomic Stability	Average Inflation Rate	%	WDI.	Reflects price stability.
External Stability	Exchange Rate	Domestic currency per US $	WDI.	Indicates external-sector conditions.
Economic Performance	GDP Growth	%	WDI.	Captures economic performance.
Sustainable Finance	Green Bond Issuance	US$ billion	IMF Climate Change Indicators database.	Reflects development of climate-related finance.

5.1 Analyses across monetary policy era

Pre-1980 (Monetarist Era): There is no evidence of climate risk concern before 1980. It was easier for monetary policy to focus on the traditional objectives of money supply control, full employment, and economic growth. Policy rates were relatively high in Canada, India, the United Kingdom, and the United States during the monetarist era, and average inflation rates were also high. Economies grew moderately, with growth rates between 2% and 7%, and there was limited awareness of environmental implications. The absence of green finance reflects the lack of climate-related issues in policy discussions.

1980–2007 (Inflation Targeting Era): Monetary policy in this era nearly achieved its primary objective of price stability, as average inflation rates declined substantially. Average inflation rates were kept below 5%, except in India and China. Climate risk concerns remained minimal, although average greenhouse gas emissions increased significantly, especially in China, India, and the United States.

2008–2019 (Post-GFC Era): This period was marked by a significant decline in monetary policy rates, linked to the support required for economic recovery during the recession, as central banks implemented accommodative monetary policies in response to the Global Financial Crisis (Committee on the Global Financial System, 2019). The following 11 years may have seen greater price stability than the previous period. However, the average macroeconomic growth rate declined during this period. This may reflect the slow recovery associated with global recessions. Climate risk concerns and carbon emissions continued to

rise, except in Switzerland. During this era, sustainable finance became more prominent for countries. The period is therefore marked by increasing environmental concerns, and the Paris Agreement, signed in 2015, falls within this timeframe.

2020–2025 (Post-COVID and Climate Era): Climate risk became increasingly relevant in the post-COVID era. Although some countries recorded lower average emissions and fewer climate risk indicators compared to earlier periods, average climate risk and carbon emissions indicate persistent climate-related challenges across almost all countries, with figures increasing substantially for the United States. This highlights the continued intensity of extreme weather events and climate-related disruptions. Sustainable finance became more significant as average green bond issuance, which was virtually nonexistent in previous policy eras, grew rapidly during this period. Green bond markets expanded more quickly in Canada, China, Japan, and the United Kingdom than in Australia, India, Switzerland, and the United States. The Asian countries and the United States recorded relatively high climate vulnerability, but green bond markets in Switzerland and India remain less developed.

The descriptive evidence shows a gradual shift in monetary policy across the eight sampled countries. Earlier regimes primarily focused on inflation management and macroeconomic growth, while climate considerations began to emerge in the post-GFC era, even though the main focus at that time remained macroeconomic stability. Climate-related concerns received unprecedented attention in monetary policy during the post-COVID period. During this time, most central banks increased their sustainable finance initiatives, and in most countries, average levels of climate risk and carbon emissions did not rise. These differences across monetary policy regimes indicate that there are heterogeneous climate-related challenges and vulnerabilities. Central banks in countries with higher climate-related risks may face stability challenges caused by supply-side disruptions. Where sustainable finance is less developed, there may be a need to integrate climate considerations into monetary policy. These analyses suggest that although climate change has become a common challenge for central banks, the specific monetary policy implications differ according to each country's climate exposure and financial market development. Thus, it can be concluded that monetary policy has gradually evolved from a simple inflation-management framework to a broader framework that incorporates climate-related economic and financial risks. These are contemporary economic and sustainability challenges that require sustainable finance developments to address shocks that traditional monetary policy frameworks were not designed to manage.

Table 5. Australia – Average values of monetary policy, climate risk, and economic indicators across monetary policy regimes

Monetary Policy Era		Pre-1980 (Monetarist Era)	1980 – 2007 (Inflation Targeting Era	2008 – 2019 (Post-Global Financial Crisis Era)	2020 – 2025 (Post-COVID and Climate Era)
Monetary Policy	Average Central Bank's Policy Rate (%)	9.10	9.42	2.99	2.36
Climate Risk	Climate physical risk index	---	4.62	4.52	4.42
Carbon Footprint	CO2 emissions	206.29	301.13	408.00	383.25
Macroeconomic Stability	Average Inflation Rate (%)	10.69	4.81	2.28	3.81
External Stability	Exchange rate	0.87	1.36	1.20	1.45
Economic performance	GDP Growth	2.7	3.34	2.64	2.22
Sustainable Finance	Green Bond Issuance	---	---	1.33	6.48

Table 6. Canada – Average values of monetary policy, climate risk, and economic indicators across monetary policy regimes

Monetary Policy Era		Pre-1980 (Monetarist Era)	1980 – 2007 (Inflation Targeting Era	2008 – 2019 (Post-Global Financial Crisis Era)	2020 – 2025 (Post-COVID and Climate Era)
Monetary Policy	Average Central Bank's Policy Rate (%)	7.91	7.38	1.08	2.44
Climate Risk	Climate physical risk index		2.50	2.50	4.40
Carbon footprint	Carbon Emissions (million tonnes)	429.40	485.61	578.40	566.22
Macroeconomic Stability	Average Inflation Rate (%)	8.41	3.77	1.67	3.44
External Stability	Exchange rate	1.09	1.31	1.16	1.32
Economic performance	GDP Growth	4.22	2.69	1.72	1.64
Sustainable Finance	Green Bond Issuance	---	---	2.98	13.20

Table 7. China – Average values of monetary policy, climate risk, and economic indicators across monetary policy regimes

Monetary Policy Era		Pre-1980 (Monetarist Era)	1980 – 2007 (Inflation Targeting Era	2008 – 2019 (Post-Global Financial Crisis Era)	2020 – 2025 (Post-COVID and Climate Era)
Monetary Policy	Average Central Bank's Policy Rate (%)		0.69	5.38	3.54
Climate Risk	Climate physical risk index		14.86	24.17	12
Carbon footprint	Carbon Emissions (million tonnes)	1444.25	3293.32	10242.42	12636.13
Macroeconomic Stability	Average Inflation Rate (%)	---	6.45	2.59	1.17
Economic performance	GDP Growth	6.23	10.09	7.97	4.89
Sustainable Finance	Green Bond Issuance	---	---	21.13	40.51
Monetary Policy	Average Central Bank's Policy Rate (%)		0.69	5.38	3.54

Table 8. India – Average values of monetary policy, climate risk, and economic indicators across monetary policy regimes

Monetary Policy Era		Pre-1980 (Monetarist Era)	1980 – 2007 (Inflation Targeting Era	2008 – 2019 (Post-Global Financial Crisis Era)	2020 – 2025 (Post-COVID and Climate Era)
Monetary Policy	Average Central Bank's Policy Rate (%)	7.96	9.47	6.79	5.33
Climate Risk	Climate physical risk index		11.04	15.00	13
Carbon footprint	Carbon Emissions (million tonnes)	274.64	759.13	2098.49	2786.07
Macroeconomic Stability	Average Inflation Rate (%)	2.37	7.99	7.26	5.81
External Stability	Exchange rate	8.50	28.41	57.72	78.58
Economic performance	GDP Growth	2.35	5.95	6.44	5.44
Sustainable Finance	Green Bond Issuance (billion$)	---	---	1.74	4.11

Table 9. Japan – Average values of monetary policy, climate risk, and economic indicators across monetary policy regimes

Monetary Policy Era		Pre-1980 (Monetarist Era)	1980 – 2007 (Inflation Targeting Era	2008 – 2019 (Post-Global Financial Crisis Era)	2020 – 2025 (Post-COVID and Climate Era)
Monetary Policy	Average Central Bank's Policy Rate (%)	5.85	3.19	0.05	0.07
Climate Risk	Climate physical risk index		3.8	6.33	4.80
Carbon footprint	Carbon Emissions (million tonnes)	1005.74	1146.80	1227.65	1033.13
Macroeconomic Stability	Average Inflation Rate (%)	6.36	1.24	0.39	1.65
External Stability	Exchange rate	248.66	146.45	100.77	127.98
Economic performance	GDP Growth	4.78	2.49	0.43	0.21
Sustainable Finance	Green Bond Issuance	---	---	2.31	21.32

Table 10. Switzerland – Average values of monetary policy, climate risk, and economic indicators across monetary policy regimes

Monetary Policy Era		Pre-1980 (Monetarist Era)	1980 – 2007 (Inflation Targeting Era	2008 – 2019 (Post-Global Financial Crisis Era)	2020 – 2025 (Post-COVID and Climate Era)
Monetary Policy	Average Central Bank's Policy Rate (%)	3.10	3.13	0.00	0.21
Climate Risk	Climate physical risk index	---	1.85	1.38	1.80
Carbon footprint	Carbon Emissions (million tonnes)	42.82	44.57	42.17	35.09
Macroeconomic Stability	Average Inflation Rate (%)	1.92	2.27	0.18	1.18
External Stability	Exchange rate	2.09	1.57	0.98	0.92
Economic performance	GDP Growth	0.98	1.93	1.66	1.69
Sustainable Finance	Green Bond Issuance	---	---	1.64	3.83

Table 11. United Kingdom – Average values of monetary policy, climate risk, and economic indicators across monetary policy regimes

Monetary Policy Era		Pre-1980 (Monetarist Era)	1980 – 2007 (Inflation Targeting Era	2008 – 2019 (Post-Global Financial Crisis Era)	2020 – 2025 (Post-COVID and Climate Era)
Monetary Policy	Average Central Bank's Policy Rate (%)	9.78	8.32	0.86	2.70
Climate Risk	Climate physical risk index	---	2.45	2.80	2.40
Carbon footprint	Carbon Emissions (million tonnes)	644.55	567. 92	440.08	315.96
Macroeconomic Stability	Average Inflation Rate (%)	13.52	4.35	2.18	4.30
External Stability	Exchange rate	0.53	0.61	0.67	1.01
Economic performance	GDP Growth	2.83	2.60	1.25	0.78
Sustainable Finance	Green Bond Issuance (billion $)	---	---	2.22	28.05

Table 12. United States – Average values of monetary policy, climate risk, and economic indicators across monetary policy regimes

Monetary Policy Era		Pre-1980 (Monetarist Era)	1980 – 2007 (Inflation Targeting Era	2008 – 2019 (Post-Global Financial Crisis Era)	2020 – 2025 (Post-COVID and Climate Era)
Monetary Policy	Average Central Bank's Policy Rate (%)	7.22	6.43	0.68	2.84
Climate Risk	Climate physical risk index		19.86	22.17	24.67
Carbon footprint	Carbon Emissions (million tonnes)	4943.08	5258. 45	5212. 95	4657.49
Macroeco nomic Stability	Average Inflation Rate (%)	7.78	3.85	1.77	4.20
External Stability	Exchange rate	1.00	1.00	1.00	1.00
Economic performan ce	GDP Growth	4.68	3.04	1.79	2.42
Sustainabl e Finance	Green Bond Issuance (billion $)	---	---	0.78	5.82

6. Conclusion

This chapter of this book have shown how monetary policy has evolved from a narrow focus on inflation targeting to a broad policy framework incorporating macroeconomic resilience, financial stability and climate sustainability. Conventional monetary policy was historically rooted in monetarist and Keynesian traditions focused on demand shocks resulting from the business cycle and financial shocks using conventional policy instruments such as policy interest rate and money supply. This chapter's evidence shows that present macroeconomic conditions reflect increasingly the persistent structural shocks of climate change, geopolitical fragmentation, technological transformation, and global pandemics that challenge the very foundation of the macroeconomic frameworks used to guide monetary policy. As the experience of Australia, Canada, China, India, Japan, Switzerland, the United Kingdom and the United States has illustrated, inflation targeting brought about an important improvement in price stability when climate risk was not on the policy agenda and the sustainable finance market was still at its beginning. However, the post-GFC and post-COVID periods have been characterized by an extension of climate-related considerations to central banking through green finance, climate-related financial supervision and an extension of macroprudential policy. The last 20 years of experience suggests that monetary policy has entered a new mode where climate change should be addressed alongside the customary objectives of price stability and financial stability.

This Chapter further argues that climate change is no longer just an environmental issue but a structural macroeconomic one because climate-related risks can increasingly transmit through aggregate supply, aggregate demand, financial stability, exchange rates, and inflation persistence. This can make the use of monetary policy interest rate changes in isolation insufficient to stabilize an economy when climate change causes supply-side shocks and hits productive capacity and when it incurs costs and risks that must be borne on the way to the low-carbon energy transition. These results support an expanded use of climate stress testing, green refinancing, climate-adjusted collateral frameworks, sustainable finance, and the use of macroprudential policy as part of a wider climate-focused monetary policy framework. This would not, however, replace the customary mandates of monetary policy, but complement them by making economies more resilient to long-term climate and systemic challenges. In this chapter, we outline the theoretical and policy context for a new model of central banking and monetary policy that is compatible with achieving the price and financial stability goals of monetary policy while accelerating the transition to sustainable and climate-resilient economic systems.

In all, this chapter has provided useful conceptual and descriptive evidence on how climate risk is changing the landscape for monetary policy, but some limitations to its findings indicate avenues for future research. First, this chapter's use of descriptive statistics is helpful for showing broad trends for monetary policy, but cannot show causal links between climate risk, sustainable finance, and macroeconomic variables. Second, while the comparative analysis covered the eight largest countries and ensured that countries from different monetary policy and climate policy regimes were included, these results cannot necessarily be generalized to low-income and climate vulnerable countries, such as those in Africa, where the financial systems and institutional quality (and therefore climate vulnerability) are considerably different. Future research could use econometric methods (panel data models, SVAR, DSGE, Bayesian estimation, Panel Threshold) to analyze the impact of climate risk on monetary policy transmission in advanced vs. developing economies. Furthermore, more research on the interplay of monetary and fiscal climate policies and the design of monetary climate policies is warranted, as is more understanding of the potential medium- and long-term effects of green finance on inflation dynamics, financial stability and economic growth. By doing so, we could contribute to a better understanding of the new role of central banks and of how with better data it is possible to implement more efficient monetary policy frameworks suitable for the twenty-first century.

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Digitalization, Artificial Intelligence and The Future of Macroeconomics

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Abstract

This chapter offers a systematic assessment of the macroeconomic consequences of digitalization and artificial intelligence in light of the theoretical frameworks and empirical findings of the economics literature. Its central claim is that the transmission of technological innovation into macroeconomic aggregates is neither automatic nor linear; it is conditioned by complementary capital investment, organizational restructuring, market structure, the institutional framework and policy choices. The claim is developed across four domains. First, on growth and productivity, the chapter shows that the "productivity paradox" is a persistent phenomenon along the trajectory from information technology to generative artificial intelligence, and that the passthrough from strong micro-level gains to aggregate total factor productivity is constrained by task coverage, adoption speed and intangible capital accumulation. Second, on labor markets, it argues that the unit of analysis should be the task rather than the occupation, and that the net employment outcome is determined by the balance between displacement and reinstatement effects. Third, on price stability, it discusses how digitalization reshapes the slope of the Phillips curve by increasing price flexibility and deepening market concentration, and how artificial intelligence may prove inflationary in the short run through demand and investment channels while being disinflationary in the medium run through supply channels. Fourth, on public policy, it examines the capital-favoring asymmetry of existing tax systems, the measurement limits of national accounts and the decisive role of competition policy in shaping the direction of technology. The chapter concludes with an assessment for developing economies and Türkiye, finding that firm-level artificial intelligence adoption in Türkiye lags markedly behind the European

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Union average, and that policy priority should therefore rest on complementary investment and diffusion rather than on frontier technology production.

Keywords: Digitalization, Artificial Intelligence, Total Factor Productivity, Task-Based Automation, Macroeconomic Policy

JEL Classification: O33, O47, E24, E31, J24

1.Introduction

Ever since Solow's (1957) growth accounting study, economists have treated it as settled that technological change is the fundamental determinant of long-run growth. The follow-up question is less settled: which technology will be transmitted into macroeconomic indicators, under which conditions, to what extent, and with how long a lag. Artificial intelligence (AI) has posed that question anew in the 2020s, and in sharper form. Measured productivity gains from generative artificial intelligence applications in particular tasks are striking; set against them, the rate of total factor productivity (TFP) growth in advanced economies has run markedly below its historical averages since the mid-2000s. The tension between these two observations is one of the most important open questions in contemporary macroeconomics.

Rather than deflect the tension in question by declaring “uncertainty,” this chapter sets out to disentangle which mechanisms produce which outcomes under which conditions, drawing on the theoretical frameworks and the validated empirical findings in the literature. Its central claim is the following: *the transmission of technological innovation into macroeconomic indicators is not an automatic and linear process; it is a delayed and path-dependent process conditioned by complementary capital investment,*[2] *organizational restructuring, market structure, the institutional framework, and economic policy choices.* That claim cuts against both the optimistic and the pessimistic projections that rest on technological determinism. The macroeconomic impact of artificial intelligence turns less on the intrinsic properties of the technology itself than on which tasks it is applied to, how rapidly it diffuses, which complementary investments support it, and under which institutional arrangements it is developed.

In scope and method, this chapter is a literature review and conceptual synthesis. It is organized around the following axes: the conceptual framework of

[2] Emphases have been provided by the author of this chapter unless otherwise stated.

digitalization and artificial intelligence together with theoretical approaches to technological change; the productivity paradox and the debate over complementary capital, taking the information technology experience as the point of departure; the micro-level productivity findings on generative artificial intelligence and the debates over the transmission of these findings into macroeconomic growth; effects on the labor market, distribution, and inequality; price stability and monetary policy; public finance, taxation, and measurement problems; the global economy and developing economies; an assessment from the perspective of Türkiye; and finally the core macroeconomic implications.

2. Conceptual and Theoretical Framework

2.1. Digitalization, the Digital Economy, and Artificial Intelligence: Definitional Distinctions

Public debate frequently uses digitalization, artificial intelligence, and automation interchangeably. In economic analysis, however, the three denote distinct phenomena. Clarifying these distinctions is critical for correctly situating the macroeconomic mechanisms discussed in the sections that follow.

Goldfarb and Tucker's (2019) comprehensive survey, which systematically treats the digital economics literature, defines the economic essence of digitalization as *a radical decline in certain types of cost*, and on their account, digitalization reduces five basic cost categories: search costs, replication costs, transportation costs, tracking costs, and verification costs. What gives the framework its analytical power is that it lets digitalization be treated less as a "technology" than as a *change in relative prices*. Cheaper search transforms the character of market matching; replication costs approaching zero transform the supply structure of information goods; cheaper tracking transforms contract design and pricing strategies. The macroeconomic effects of digitalization should, therefore, be read as a structural transformation that alters the way markets operate, rather than as an input added to the production function.

Artificial intelligence, by contrast, is a family of technologies situated within this broader process of digitalization but possessing a distinctive economic character. Agrawal et al. (2019) define its economic essence as *a technology that lowers the cost of prediction*. That definition yields a powerful analytical framework independent of technical detail: advances in machine learning essentially reduce the cost of deriving missing information from incomplete information. Prediction on its own, however, carries no value; it is an input into a decision process. Cheaper prediction, they underscore, has an *ambiguous* effect on the labor market.

When prediction becomes cheaper, two different outcomes may follow: the decision may be automated in its entirety, in which case human labor is substituted for; or better prediction may be supplied to the human decision maker, so that the task of "judgment" is complemented and labor demand rises. Which outcome materializes follows from the structure of the decision and the nature of the task, not from the technology itself.

After 2022, generative artificial intelligence added a new dimension to this picture. Because large language models can produce text, code, and images, the focus of the automation debate has moved away from routine manual and routine cognitive tasks and toward the writing, summarization, analysis, and software development tasks that have traditionally been regarded as "nonroutine cognitive." That shift also alters the position of the exposure distribution along the skill axis, as later sections discuss.

2.2. Technological Change and Economic Growth: Theoretical Foundations

Technological change entered macroeconomic analysis with Solow's (1957) growth accounting study. Working with United States data for the 1909–1949 period, Solow showed that approximately seven-eighths (87.5%) of the increase in real gross output per man-hour derived from technological change, and only one-eighth (12.5%) from the increase in capital per man-hour. Out of that finding came the concept later termed the "Solow residual." Its limitations are as evident as its conceptual importance. The residual holds together everything that cannot be measured directly: technological progress, organizational efficiency, the quality of resource allocation, and measurement error. That limitation is, in a sense, where the measurement debate taken up in later sections begins.

Because the Solow model treated technological progress as exogenous, the long-run growth rate was determined outside the model. Romer (1990) overcame this limitation by endogenizing technological progress through R&D investment, the accumulation of knowledge, and economic incentives. In Romer's framework, knowledge is distinguished by being *nonrival* while, by contrast, only partially *excludable*. Nonrivalry means that the same idea can be used simultaneously in an unlimited number of production processes, a property that is a source of increasing returns to scale. Partial excludability, in turn, makes innovation profitable and, therefore, makes its production by the private sector possible. The model's central policy implication is this: Competitive markets invest in research below the social optimum. In the context of artificial intelligence, that implication

cuts twice: on the one hand, the potential of artificial intelligence to accelerate growth by raising the capacity for idea production; on the other, the question of whether artificial intelligence research is itself being conducted at a socially adequate level and in the right direction.

Where the neoclassical mainstream of growth theory models technology either as an exogenous parameter or as an endogenous output of R&D investment, the institutional economics tradition has treated technological change as a process inseparable from institutional structure. Dura and Güler (2022) compare two founding figures of that tradition, J. A. Schumpeter and T. Veblen, and place the subject within a framework directly relevant to the argument of this chapter. Their distinction runs as follows. In Schumpeter, the process of technological development that determines creative destruction unfolds *within* the system but affects the market as though it were an exogenous factor; knowledge accumulates out of the profit motive of firms seeking advantage under market conditions, and institutional structure performs a relatively passive function in this process. In Veblen, by contrast, technological change and economic growth are integrated with institutional structure: Institutions reflect society's habits of thought, and these habits change only through technology. The Veblenian distinction they identify between the "imbecile institutions", which resist change and have become entrenched as established rules, and the "dynamic technical institutions", which are the source of change, shows that institutional structure can be both an obstacle to and a facilitator of technological change. Causality, in their account, runs in both directions: while the individual gives rise to technological change, technological progress in turn transforms the habits of thought of the individual and of society, thereby triggering institutional change.

This approach does two things: It lends theoretical depth to the claim that the macroeconomic outcome of technology cannot be considered independently of institutional structure; and long before the contemporary debate on artificial intelligence, it raised the possibility that institutional structure may use technological progress in a manner that preserves the status quo rather than transforming it.

Aghion et al. (2019) model the effect of artificial intelligence on idea production directly, carrying the logic of Baumol's cost disease into the artificial intelligence context. The basic insight is this: As the relative price of automated tasks falls, the tasks cannot be automated but they remain indispensable for production resulting in the increase in their share in total output and becoming the bottleneck that constrains growth. Even extraordinary productivity gains in some tasks may, therefore, fail to accelerate aggregate growth proportionally. A growth

"singularity" is mathematically possible, they also show, under certain theoretical conditions, such as full automation of the idea production function or a recursively self-improving artificial intelligence; they emphasize, however, that Baumol-type bottlenecks may prevent such explosive growth even under strong automation.

Against this theoretical optimism stands an empirical literature documenting the difficulties on the supply side of innovation, and it must also be taken into account. Research productivity has declined dramatically over the long run (Bloom et al., 2020). Sustaining the doubling of chip density predicted by Moore's Law now takes more than 18 times as many researchers as it did in the early 1970s. For the United States economy as a whole, research productivity has fallen by a factor of 41 since the 1930s, an average decline of more than 5 percent per year, while over the same period the number of researchers increased by a factor of 23 (4.3% per year). This finding sets an important boundary condition on optimistic scenarios regarding the effect of artificial intelligence on growth. If artificial intelligence can reverse this structural decline in research productivity, its growth effect will be large; if it cannot, it will remain merely a factor that slows the pace of the decline.

Gordon (2016) makes the most comprehensive case for technological pessimism along the same lines. In his long-run data, average annual total factor productivity growth in the United States was 1.89 percent over the 1920–1970 period, fell to 0.57 percent over 1970–1994, rose to 1.03 percent during the revival driven by information technologies (1994–2004), and then declined to 0.40 percent over 2004–2014. His central claim is that the cluster of "great inventions" of the mid-twentieth century (electricity, the internal combustion engine, modern sanitation, chemicals, and telecommunications) is not repeatable, and that the impact of digital technologies has remained confined to a narrow domain by comparison with that cluster. On this basis, he projects growth in GDP per capita for the 2015–2040 period at only approximately 0.8 percent per year. For the debate on artificial intelligence, that projection functions less as a forecast than as a *burden of proof*: any framework that defends the macroeconomic significance of artificial intelligence must explain why and how this historical trend will be broken.

2.3. The General-Purpose Technology Approach and the Position of Artificial Intelligence

Much of the debate over the macroeconomic significance of artificial intelligence turns on whether this technology is a *general-purpose technology*. General-purpose technologies spread across a broad segment of the economy, improve

continuously, and trigger complementary innovations. Steam power, electricity, and information technologies are the canonical examples.

Situating artificial intelligence within this historical framework, Crafts (2021) offers an important perspective. His main point is qualitative but decisive for policy: General-purpose technologies have produced their large macroeconomic effects only *with a substantial lag*. What generates the lag is not the technology itself; it is the time required for the complementary infrastructure, organizational forms, and accumulation of skills needed for its widespread use to take shape. As of the date of his writing, Crafts records, artificial intelligence had not yet produced a meaningful effect on aggregate productivity. That historical perspective serves as an important corrective. It tempers short-term expectations regarding artificial intelligence.

Agrawal et al. (2025) apply the general-purpose technology framework to the context of artificial intelligence in a current formulation, arguing that adoption patterns are jointly determined by *co-invention costs* and technology-specific benefits. Cheap prediction, the core benefit of artificial intelligence, creates a distinctive coordination problem among decision makers: The value of a prediction input depends on redesigning the decisions that will use it, and that redesign may require a transformation extending beyond the boundaries of the firm. Early productivity gains from artificial intelligence, they observe, have been concentrated in firms with integrated data and workflow systems. The reason is that co-invention costs are lower in such firms.

2.4. The Task-Based Framework: Displacement and Reinstatement

Contemporary automation economics rests on the task-based framework, whose origins lie in the work of Autor et al. (2003). Technology, they establish, transforms not occupations as wholes but the *tasks* that occupations contain. Computerization substitutes for labor in the routine cognitive and routine manual tasks that can be defined in rule-based terms while it complements labor in the nonroutine tasks that require problem solving and complex communication. Their quantitative findings demonstrate the explanatory power of this distinction. Computerization accounts for 30–40 percent of the relative demand shift in favor of college-educated labor observed over the 1970–1998 period. More importantly, changes in task content *within* occupations that remain nominally the same account for more than half of the total demand shift attributable to computerization. That second finding shows directly why framing the question as "how many occupations are open to automation?" is inadequate.

Acemoğlu and Restrepo (2018) transform this insight into a full macroeconomic growth model. Two opposing forces operate in it simultaneously. *The displacement effect* reduces labor demand: automation substitutes capital for labor in existing tasks. *The reinstatement effect*, by contrast, raises labor demand by creating new tasks in which labor holds a comparative advantage. A balanced growth path can exist only if these two forces advance together, and that is the model's critical result. Their empirical demonstration establishes how much the mechanism matters quantitatively: approximately half of the 17.5 percent increase in total employment in the United States over the 1980–2007 period is accounted for by the additional employment growth in occupations containing new job titles.

Acemoğlu and Restrepo's (2019) accounting quantifies the change in the historical balance between these two effects. Over the 1947–1987 period, the displacement effect reduced labor demand by approximately 0.48 percent per year on average, while the reinstatement effect raised it by approximately 0.47 percent. The two forces offset each other almost exactly. Over the 1987–2017 period, by contrast, the picture changed: The displacement effect rose to approximately 0.7 percent per year, while the reinstatement effect fell to 0.35 percent. In manufacturing, the displacement effect reached 1.1 percent per year, corresponding to a cumulative reduction in labor demand of approximately 30 percent. Cumulatively, this change in the task content of production reduced labor demand by approximately 10 percent over the 1987–2017 period, while growth in the wage bill fell over the same period from 2.5 percent to 1.33 percent per year and productivity growth from 2.4 percent to 1.54 percent.

Three basic implications carry over to the remainder of the study. First, what determines the net effect of automation on employment is the change in the composition of tasks, not the technology itself. Second, new tasks do not get created of their own accord; their creation depends on investment, entrepreneurship, and institutional arrangements. Third, the forms of automation that deliver no productivity gains but nonetheless substitute for labor (the form Acemoğlu and Johnson (2023) call “so-so automation”) produce the most adverse outcome for both growth and distribution.

3. The Productivity Puzzle: From Information Technology to Artificial Intelligence

3.1. The Information Technology Revolution and the 1990s Acceleration

Today's debate over the macroeconomic impact of artificial intelligence has a precedent, which is information technology (IT) in the 1990s. No historical reference point is more instructive. Robert Solow's famous 1987 observation -that the computer age could be seen everywhere except in the productivity statistics- was seemingly refuted in the second half of the 1990s. What that refutation amounted to, however, and where its limits lay, are decisive for the current debate.

Oliner and Sichel (2000) attribute roughly two-thirds of the acceleration in labor productivity in the United States between the first and the second half of the 1990s to information technology capital deepening and to efficiency gains in computer production. Working through the same period in a growth accounting framework, Jorgenson and Stiroh (2000) find output growth rising from approximately 2.7 percent per year in 1990–1995 to approximately 4.7 percent in 1995–1998, and total factor productivity growth rising from approximately 0.36 percent to 0.99 percent. Information technology, as these findings demonstrate, can generate a measurable effect at the macroeconomic level. That experience has two critical features, however. First, the lag is long: Approximately fifteen years elapsed between the point at which the personal computer began to diffuse widely and the emergence of a measurable macroeconomic effect. Second, the effect was distributed *unevenly across geographies*. van Ark et al. (2008) show the productivity gap between Europe and the United States reopening from the mid-1990s onward, with labor productivity growth slowing sharply in Europe even as it accelerated in the United States. They trace the divergence to a lower contribution from information technology investment, a smaller IT-producing sector, and slower multifactor productivity growth, and they identify *market services* as its principal source. That the same technology produces different outcomes in different economies is one of the strongest empirical objections to technological determinism.

3.2. Complementary Investments: Why Is Technology Alone Not Enough?

Whether technology translates into productivity depends on *complementary investments*; that is the most durable lesson of the information technology

experience. As Brynjolfsson and Hitt (2000) show, the productivity return to information technology investment requires complementary organizational investments such as decentralization, new business processes, and organizational restructuring. Those complementary investments are largely intangible, which is why standard productivity statistics struggle to capture them. Measured productivity, therefore, lags the value that is actually created.

At the firm level, Bresnahan et al. (2002) document this complementarity. Their factor demand and productivity regressions alike turn up evidence of complementarity among information technology, workplace reorganization, decentralization, self-managing teams, and broader job responsibilities, and the development of new products and services. Firms that adopt these three elements jointly employ more skilled labor, and information technology's effect on the demand for skilled labor grows markedly when it is combined with organizational investment.

Bloom et al. (2012) appeal to the quality of management to explain why the same technology produces different outcomes across firms. In their data, doubling the information technology capital stock raises productivity by approximately 6.3 percent in the foreign affiliates of U.S.-headquartered multinationals, whereas in non-U.S.-headquartered or domestic establishments the increase is only about 4.6 percent. U.S. firms score more than half a standard deviation higher on structured people management practices. That management gap statistically accounts for the U.S. information technology advantage. That stronger IT–productivity relationship is, they argue, large enough to explain roughly half of the "productivity miracle" that the United States experienced relative to Europe.

All three studies converge on one implication, and it carries over directly to artificial intelligence. What artificial intelligence investment returns at the macroeconomic level will depend on how much complementary investment goes into data infrastructure, redesigned business processes, worker training, and managerial capacity. Access to the technology is a necessary but not a sufficient condition.

3.3. The Modern Productivity Paradox and the Productivity J-Curve

Macroeconomic productivity indicators have responded so slowly despite rapid advances in artificial intelligence, and Brynjolfsson et al. (2019) work systematically through four possible explanations for why. Those explanations

are false hopes -the technology promising less than expected-, mismeasurement, redistribution and rent shifting, and implementation lags.

They conclude that the evidence most strongly supports the *implementation lags* explanation. Before the capabilities of artificial intelligence can register in aggregate statistics, complementary investments such as organizational capital and business process redesign must first come to fruition.

Formally, this insight became the *productivity J-curve*, a concept the same authors developed. In the first phase of adopting general purpose technologies, measured productivity *can decline*, as Brynjolfsson et al. (2021) show. This happens because firms invest in unobserved complementary intangible such assets as software, data, organizational processes, and human capital; the cost of these investments reduces current-period output, and the assets they create are not recorded as capital in the national accounts. Once the complementary investments come to fruition, productivity growth becomes visible. Measured productivity then rises above true productivity, which is the upward arm of the letter J.

Their quantitative findings indicate how large this mechanism is. Once the measurement correction is applied, true total factor productivity is estimated to be 11.3 percent higher than the official measures as of the end of 2004, and 15.9 percent higher as of the end of 2017. J-curve effects concentrate in software-related intangible investment and are more limited in hardware. For artificial intelligence, the most striking result in the study is a ratio: Each measured dollar of artificial intelligence investment may require an estimated 2.7 to 4.1 times as much unmeasured complementary intangible investment. That ratio explains quantitatively why gains observed at the micro level can take so long to appear in macroeconomic statistics.

The debate over intangible capital carries independent importance for understanding the economic logic of the digital economy. Haskel and Westlake (2018) set out systematically the four distinguishing properties of intangible assets, which are scalability, sunkenness, spillovers, and synergies. Additionally those properties explain why intangible-intensive economies exhibit greater monopoly power, higher inequality, and investment patterns that are harder to finance. In Corrado et al.'s (2021) framing, artificial intelligence is a bundle of intangible assets composed of software, data, and algorithms; conventional productivity statistics, they argue, systematically understate what artificial intelligence contributes.

Most recently, this literature has begun to treat data itself as a form of capital. Across the nine European countries examined by Bontadini et al. (2025), approximately half of intangible capital consists of *data capital*. On their

estimates, data-based efficiency gains raise labor productivity by approximately 0.2 percentage points per year; by contrast, the weaker knowledge spillovers that follow from data being subject to ownership *lower* total factor productivity growth by an estimated 0.3–0.4 percentage points per year. That finding matters critically for policy, because it shows that the data ownership regime can affect macroeconomic productivity directly and that the net effect can be negative.

3.4. Can the Measurement Problem Be an Explanation?

One claim recurs throughout the debate: the productivity slowdown is an artifact of measurement rather than something real. Testing it empirically is also directly decisive for the debate over artificial intelligence: If the national accounts systematically undermeasure the value the digital economy creates, the observed productivity slowdown may be an illusion.

Byrne et al. (2016) test this claim directly on U.S. data and find no supporting evidence. There is, they report, "little evidence" that the slowdown arises from the increasing mismeasurement of the gains from innovation in information-technology-related goods and services. Adding the market value of all free digital media properly to the growth aggregates would raise GDP growth by only "a few basis points." More striking still, corrections to the measurement of information technology *deepen* the labor productivity slowdown rather than mitigating it because U.S. production of information technology has itself also slowed since 2004.

Syverson (2017) puts the same claim through four independent tests. First, the productivity slowdown shows up in "dozens of countries," and its magnitude appears unrelated to how intensively the countries in question produce or consume information technology. Second, existing estimates of internet-based digital consumer surplus "fall far short of" the $3 trillion or more of "missing output" implied by the slowdown. Third, gross domestic income has on average exceeded GDP since 2004, but that excess reflects unusually high capital income (profits) rather than mismeasured labor payments, and it began before the slowdown.

Together, these two studies establish strongly that the measurement problem cannot be the *principal* explanation for the productivity slowdown. That does not make the measurement problem unimportant, however. To capture the welfare contribution of free digital goods, Brynjolfsson et al. (2019) propose a welfare measure complementary to GDP (GDP-B). Over 2003–2017, they put Facebook's cumulative welfare contribution in the United States at $231 billion, or $1,143 per user. Folding that welfare gain in adds 0.05–0.11 percentage points per year to the

GDP-B measure: Average annual real GDP growth of 1.83 percent becomes 1.91 percent under GDP-B. Nakamura et al. (2017) calculate that if free digital and print content were included, real GDP growth over 2005–2015 would be 1.53 percent rather than the official 1.42 percent.

What these estimates share is that the corrections are *real but modest at the macroeconomic level*. Corrections on the order of 0.1 percentage points per year are cumulatively meaningful over the long run, but they fall well short of accounting for the magnitude of the productivity slowdown. In the age of artificial intelligence, Coyle and Nguyen (2019) note, the problem may deepen: The quality-adjusted prices of cloud computing services have fallen rapidly over the past decade, yet official deflators have not reflected that decline; moreover, the cross-border fragmentation of value chains and the growing reliance on intangible intermediate inputs such as intellectual property and data are often not captured at all in existing statistics.

4. From Micro Findings to Macro Outcomes: The Productivity Effect of Artificial Intelligence

4.1. Experimental and Field Findings

What distinguishes the empirical literature on the productivity effect of generative artificial intelligence is its base: A body of micro evidence that has accumulated rapidly and that is methodologically strong. That evidence comes from methods well suited to causal inference, randomized controlled trials and staggered rollout designs among them.

In a controlled experiment conducted with 453 college-educated professionals, Noy and Zhang (2023) show that access to ChatGPT reduced the average completion time of occupational writing tasks by 40 percent and raised the quality of output by 18 percent, approximately 0.45 standard deviations. The study's most important finding, from a distributional standpoint, is that performance inequality compresses. In the control group, the correlation between a participant's scores on the first and the second task is 0.41. In the treatment group it falls to 0.14. In other words, the lowest initial performers gain the most.

Brynjolfsson et al. (2025) put the same finding to the test under real workplace conditions. Their natural experiment is the staggered rollout of access to a conversational assistant based on generative artificial intelligence among 5,172 customer service workers. Access to the tool raises productivity, measured by the number of issues resolved per hour, by 14 percent on average. Among

inexperienced and low-skilled workers the effect reaches 34 percent. Among experienced and high-skilled workers, by contrast, it remains negligible. They also present evidence that the tool improves customer satisfaction and employee retention, and that it mediates the diffusion of the techniques of the most successful workers to newer workers.

Autor's (2024) broader synthesis assesses these findings. In the evidence he compiles, GitHub Copilot raises the task completion speed of programmers in the treatment group by approximately 56 percent; ChatGPT assistance reduces the time required for writing tasks by approximately 40 percent; and AI assistance in customer service delivers a productivity gain of approximately 14 percent, while shortening the time needed to move from novice to experienced from roughly ten months to three months. The policy argument he draws from these findings is noteworthy.

By opening judgment tasks that require expertise to a broader body of workers, artificial intelligence carries the potential to rebuild middle-class jobs. Whether that potential is realized, however, depends on the direction in which the technology is developed.

4.2. The Jagged Technological Frontier and Heterogeneity

Dell'Acqua et al. (2026) offer the most important corrective to a one-sided reading of the micro findings. In a preregistered field experiment conducted with 758 management consultants, they show that the effect of artificial intelligence differs fundamentally depending on whether the task falls inside or outside the boundaries of the technology's capability.

For tasks that lie *inside* the frontier of AI capability, the findings are strongly positive: consultants using artificial intelligence completed 12.2 percent more tasks, worked 25.1 percent faster, and produced output more than 40 percent higher in quality. For a task lying *outside* the current capability of the technology, by contrast, the picture reverses. AI-assisted consultants were 19 percentage points less likely to produce a correct solution; The accuracy rate was 84.5 percent in the control group but fell to a range of approximately 60–70.6 percent in the AI conditions.

This phenomenon, which the authors call the “jagged technological frontier,” carries considerable macroeconomic significance. The frontier of AI capability does not coincide with the observed difficulty of tasks: a task that appears easy

for a human may lie outside the frontier for artificial intelligence, while a task that appears difficult for a human may lie inside it. Under such irregularity, the adoption decision itself becomes a costly learning process. It also indicates that firms may experience productivity losses if they fail to identify correctly which tasks to apply artificial intelligence to. Inside the frontier, low-performing consultants again gain the most, and that confirms the findings of Noy and Zhang (2023) and Brynjolfsson et al. (2025).

4.3. Firm-Level Adoption, Growth, and the Speed of Diffusion

Firm-level evidence indicates that investing in artificial intelligence yields a measurable return in performance. Babina et al. (2024) work with a firm-level measure of AI investment derived from resume and job posting data. A one standard deviation increase in AI investment intensity, they find, raises sales growth by approximately 19.5 percent, employment growth by 18.1 percent, and market value growth by 22.3 percent over an eight-year period. These effects come *from such product innovation as* patents, trademarks, and new products, rather than from cost reduction or efficiency gains. They also increase with the initial size of the firm, which is important from the standpoint of concentration. The share of employees with AI skills within firms, meanwhile, rose from approximately 0.04 percent in 2007 to 0.29 percent in 2018.

Nonetheless, these positive firm-level findings must be read together with the *prevalence* of adoption. Drawing on data covering approximately 850,000 firms from the 2018 Annual Business Survey of the U.S. Census Bureau, McElheran et al. (2024) examine the use of five AI technologies. Fewer than 6 percent of firms reported using any of the AI technologies measured. The employment-weighted adoption rate, however, is slightly above 18 percent. The gap between these two rates indicates that adoption is concentrated among large employers. Use of artificial intelligence clusters together with cloud computing and robotics, and it is concentrated in venture-capital-backed, young, and growth-oriented firms and in “superstar” cities.

Set against earlier technologies, generative artificial intelligence has diffused at a noteworthy speed. As of the end of 2024, 39.6 percent of working-age (18–64) adults in the United States used generative artificial intelligence either at work or outside work, 26.5 percent used it at work, and 9.0 percent used it every working day (Bick et al., 2024). In the comparison they draw, the *workplace* adoption path of generative artificial intelligence, which is 27% two years after its release, is close to that of the personal computer, which is 25% in the third year; the *overall*

adoption rate (39.6%), however, markedly exceeds the rates recorded for the personal computer and the internet over comparable periods. Outside work, adoption was approximately 5 percent for personal computers, whereas for generative artificial intelligence it stands at 34 percent.

Survey data at the organizational level likewise point to rapid diffusion. Singla et al. (2025), drawing on a survey conducted with 1,491 respondents from 101 countries, report that 78 percent of organizations use artificial intelligence in at least one business function, 72% at the beginning of 2024, and that 71 percent regularly use generative artificial intelligence in at least one function, 65% in the preceding period. In the same survey, however, only 17 percent of organizations attribute 5 percent or more of their corporate operating profit to generative artificial intelligence. Widespread use limited measurable financial impact: That divergence is how the productivity paradox shows up at the firm level.

A survey conducted with approximately 750 senior executives over the November 2025–January 2026 period documents this paradox directly (Baslandze et al., 2026). More than half of the firms surveyed had invested in artificial intelligence as of 2025, and adoption is expected to reach 85.4 percent in 2026. Executives report labor productivity gains of 1.8 percent for 2025 and 3.0 percent for the expectation for 2026. Gains computed on a revenue basis, however, are markedly lower: 0.6 percent for 2025 and 1.8 percent for the expectation for 2026. Perceived gains exceed measured gains. That is current and direct evidence of the productivity paradox.

4.4. The Micro-Macro Transition Problem: The Cautious Framework

The most systematic statement of the argument that strong micro-level findings cannot be transferred directly to the macro level comes from Acemoğlu (2025). His framework rests on Hulten's theorem: A cost-saving in a given task contributes to total factor productivity in proportion to that task's share in total costs, a simple accounting relationship that explains why gains which appear very large at the micro level may remain modest at the macro level.

Acemoğlu's calculation puts the cumulative increase in total factor productivity that artificial intelligence will generate within ten years at “no more than 0.66 percent.” Once context-dependent and hard-to-learn tasks are taken into account, that estimate falls to “below 0.53 percent.” Three components drive the result: the share of the tasks that artificial intelligence can affect within total tasks, the size of the cost saving to be achieved in those tasks, and the rate of adoption.

Multiplying the three converts the striking percentages observed at the micro level into small numbers at the macro level. He argues further that since its effects are distributed more evenly across tasks, artificial intelligence may not raise inequality as much as previous waves of automation did but that there is no evidence that it reduces labor income inequality and that it will probably widen the gap between capital and labor income.

Against this cautious framework, more optimistic estimates are also available. Aghion and Bunel (2024) work through two different methods for the coming decade. One approach, based on historical general purpose technology analogies, projects additional annual productivity growth of 0.8–1.3 percentage points. Their task-based model, built on the framework of Acemoğlu (2025), by contrast, yields annual total factor productivity growth in the range of 0.07–1.24 percentage points, with a median estimate of 0.68 percentage points. The difference between the two methods shows how sensitive such estimates are to assumptions.

Filippucci et al. (2025) carry micro-level productivity findings into macro scenarios for the G7 economies, working through task exposure, the speed of adoption, and the structural characteristics of countries. Within a framework of three scenarios, annual aggregate labor productivity growth attributable to artificial intelligence over the coming decade is projected to lie in the range of 0.4–1.3 percentage points. Gains tilt in favor of the United States and the United Kingdom because of their specialization in financial, information and communication services; the projected gains of the other G7 countries are lower by up to 50 percent. For developing economies, the finding matters directly, since it shows that the macroeconomic effect of artificial intelligence depends strongly on the sectoral structure of countries. Estimates produced within the framework of the International Monetary Fund point to a similar range. Across steady states in the model scenarios of Cazzaniga et al. (2024), output rises by approximately 10 percent in the low-complementarity case and by as much as 16 percent in the high-complementarity case; total factor productivity increases by approximately 4 percent; and annual worker productivity growth in the first decade receives a contribution of close to 1.5 percentage points.

Table 1. Selected Estimates of the Macroeconomic Productivity Effect of Artificial Intelligence

Study	Method	Scope	Estimate
Acemoğlu (2025)	Task-based, Hulten's theorem	United States, 10 years	Less than 0.66% cumulative in TFP; less than 0.53% adjusted
Aghion and Bunel (2024)	Historical GPT analogy	United States, 10 years	+0.8 to +1.3 percentage points per year
Aghion and Bunel (2024)	Task-based model	United States, 10 years	0.07–1.24 percentage points per year (median 0.68)
Filippucci et al. (2025)	Micro-macro scaling, three scenarios	G7, 10 years	0.4–1.3 percentage points of labor productivity per year
Cazzaniga et al. (2024)	General equilibrium scenarios	Global	Output +10% to +16% between steady states; TFP ~+4%
Baslandze et al. (2026)	Executive survey (realized)	U.S. firms, 2025	Reported +1.8%; revenue-based +0.6%

Source: Compiled by the author from the relevant studies.

4.5. Transformative Artificial Intelligence Scenarios and Theoretical Limiting Cases

One assumption underpins the estimates above, which is the current capabilities of artificial intelligence will diffuse gradually. A separate strand of the literature examines scenarios in which that assumption may not hold.

By modeling the "race" between automation and capital accumulation, Korinek and Suh (2024) identify three qualitative regimes. In the regime where automation advances slowly, wages "can rise forever." In the regime where automation outpaces capital accumulation, an excess supply of labor emerges even before full automation is reached, and wages decline. In the full automation regime, by contrast, wages collapse. Their framework is valuable because it shows that the outcome depends less on the speed of technology than on the *relative* speed of automation and capital accumulation.

Trammell and Korinek (2026) offer a systematic synthesis of the growth literature under transformative artificial intelligence. They substantiate the following principal claims:

> Full automation through self-replicating machines "raises the growth rate dramatically and lowers the labor share; it breaks the Kaldor facts." Automating R&D, self-improving machines, accelerates the transformation but may not produce it on its own. The direction of wages is uncertain, and it depends on returns to scale, natural resource constraints, and the direction of technical change.

Nordhaus (2021) put these scenarios to an empirical test. Working through several approaches to information technology trends such as sectoral information technology output shares, the wages of information technology workers, and computer-to-output ratios, he concluded that "the singularity is not near." Under most parameterizations, the time at which the economy might cross the singularity threshold is estimated at "100 years or more." Jones (2024), by contrast, takes up the problem along a different axis, modeling jointly the potential of artificial intelligence both to accelerate growth by raising innovative capacity and to create existential risk through misaligned superintelligence. In his illustrative calibration, optimal policy under logarithmic utility can accept considerable existential risk in exchange for a gain in growth.

These theoretical limiting cases serve the chapter's overall argument in the following way: Logically, the transformative scenarios are coherent; the current empirical evidence base, however, does not support them. For policy design, it appears reasonable to build the baseline scenario on the assumption of gradual diffusion, without entirely disregarding low-probability but high-impact scenarios.

5. The Labor Market, Distribution, and Inequality

5.1. Measuring Exposure: Which Jobs, Which Tasks?

Patent texts and task descriptions overlap, and the first generation of studies proceeded from that overlap. Webb (2020) constructs an exposure measure by matching the textual content of artificial intelligence patents to occupational task descriptions, and the result inverts the robot pattern: AI exposure is concentrated among high-wage and highly educated workers, whereas robot exposure falls on the least educated groups. Webb also offers a historical comparison. Over the 1980–2010 period, a move from the 25th to the 75th percentile of robot exposure was associated with an employment decline of 9 to 18 percent and a wage decline of 8 to 14 percent. A family of indicators from Felten et al. (2021) measures AI exposure at the occupation, industry, and geographic levels, and it has become the standard data set in the field.

Once generative artificial intelligence emerged, how exposure is measured had to be redefined. Eloundou et al. (2024) assess the labor market impact potential of large language models directly at the task level. Roughly 80 percent of the U.S. workforce, they find, is in a position in which at least 10 percent of their work tasks could be affected by large language models, while roughly 19 percent of workers are in a position in which at least 50 percent of their tasks could be affected. With the language model alone, about 15 percent of all worker tasks can be completed significantly faster at the same level of quality; once language-model-based software and tools are included, this share rises to a range of 47 to 56 percent.

At the International Labour Organization (ILO), the framework built to measure exposure turns on the distinction between automation and augmentation. By the calculations of Gmyrek et al. (2023), 2.1 percent of global employment is subject to automation exposure and 13.1 percent to augmentation exposure, with a further 16.2 percent (553 million workers) falling into the "big unknown" category. The gender dimension is striking. Globally, automation exposure is 3.7 percent for female employment and 1.4 percent for male employment; in high-income countries these shares are 7.8 percent and 2.9 percent, respectively. A refined method in the updated 2025 study (Gmyrek et al., 2025) puts roughly 24 percent of global employment at some degree of exposure to generative artificial intelligence, and the highest-exposure tier at 3.3 percent globally, which is 4.7 percent for women and 2.4 percent for men.

A caveat runs through all these measurement studies, and it matters: exposure measures *potential* impact, not the realized employment effect. That a task is technically automatable does not make automating it economically profitable, organizationally feasible, or legally permissible.

5.2. From Robots to Generative Artificial Intelligence: Empirical Employment Findings

Studies of industrial robots provide the most robust evidence on the realized employment effects of automation, and that literature is instructive for a second reason as well: It shows how sensitive the findings are to institutional context.

In U.S. local labor markets, Acemoğlu and Restrepo (2020) estimate that an increase of one robot per thousand workers reduces the employment-to-population ratio by 0.2 percentage points and wages by 0.42 percent. They separate this effect from import competition from China and Mexico, the decline of routine jobs, offshoring, and other information technology capital, and they

find support for the causal claim in a further result: Areas with high robot exposure exhibited no differential trend before 1990.

German data tell a different story. Dauth et al. (2021) put the same question to the German case and reach a markedly different conclusion. Robot density there rose from roughly 2 per thousand workers in 1994 to 7.6 in 2014, against a European average of 2.7 and a U.S. figure of 1.6. Each additional robot displaces about two manufacturing jobs on average; roughly 275,000 manufacturing jobs are lost in total; and robots account for about 23 percent of the overall decline in manufacturing employment. *The effect on total local employment, however, is close to zero*: manufacturing losses are fully offset by gains in services. Most of the burden falls on young workers entering the labor market. What divides the two studies is not technology. It is labor market institutions, within-firm adjustment mechanisms, and the vocational training system.

Firm-level evidence can also diverge from aggregate evidence. In Spanish manufacturing, Koch et al. (2021) report that in firms that adopt robots output rises by 20 to 25 percent within four years, the labor cost share falls by 5 to 7 percentage points, and net employment *increases* by about 10 percent. None of this contradicts the local labor market result of Acemoğlu and Restrepo (2020). Because adopting firms gain market share at the expense of their competitors, employment rises at the firm level even as the net effect at the industry or regional level may be negative. The distinction is methodologically critical. It shows how the choice of the unit of analysis determines the results.

Panel data for the 1993–2007 period, covering 17 countries and 14 industries, let Graetz and Michaels (2018) measure the productivity effect of robots. Increased robot use contributed roughly 0.36 percentage points to annual labor productivity growth. That is about 15 percent of the 2.4 percent average increase. Gains in total factor productivity are roughly two-thirds as large as gains in labor productivity. While no significant effect is found on total hours worked, the employment share of low-skilled workers declined significantly. Wage gains, by contrast, are modest -on the order of 10 percent of the productivity gains.

Evidence on the realized employment effects of generative artificial intelligence is still at an early stage. It is accumulating rapidly all the same. Acemoğlu et al. (2022), working with U.S. establishment-level online vacancy data for the 2010–2018 period, estimate that a one standard deviation increase in AI exposure raises the growth of AI vacancies by roughly 15 to 16 percent and is associated with a decline of roughly 14 percent in non-AI vacancies, concentrated in 2014–2018.

At the occupation or industry level, however, no detectable effect on aggregate employment or wages appears.

For the 2010–2023 period, Hampole et al. (2025) build measures of firm - and occupation-level task exposure with natural language processing. At the occupation level, a one standard deviation increase in average exposure lowers the within-firm employment share by about 14.5 percent within five years; by contrast, an increase in the *concentration* of exposure raises that share by about 7.5 percent. What follows is that the decline in demand in exposed occupations is offset by the productivity-driven increase in labor demand at AI-adopting firms. The aggregate employment effect, therefore, remains modest.

Danish data supply the strongest evidence that early-stage effects are limited. Humlum and Vestergaard (2026) examine 25,000 workers, 7,000 workplaces, and 11 occupations over the 2023–2024 period; they measure average time savings at only 2.8 percent of working hours and characterize the effects on earnings and hours worked as "precisely estimated zeros." In the March 2026 update, the confidence intervals over a two-year window rule out earnings and hours effects larger than 2 percent. By contrast, roughly 19 percent of workers in the most favorable adoption environments, those who are encouraged and who have access to employer-provided tools and training, save more than one hour per day. A "task reorganization" channel also turns up in their results. Adopters moved into higher-paying occupations that are better suited to chatbots and increased their hours in these new occupations by about 4 percent of a full-time equivalent by the end of 2024.

5.3. New Findings: Entry-Level Employment and the "Canaries in the Coal Mine"

The most recent empirical literature indicates that while the effect of artificial intelligence on aggregate employment remains limited, it may be concentrated on *particular subgroups*. Using U.S. payroll data, Brynjolfsson et al. (2025) find a relative employment decline of 16 percent among early-career workers aged 22 to 25 in the occupations most exposed to artificial intelligence once firm-level shocks are controlled for. For software developers aged 22 to 25, the decline is roughly 20 percent as of 2025 relative to the peak at the end of 2022. Adjustment, they stress, operates through *hiring and headcount* rather than through wages. A follow-up note dated February 2026 argues that the decline becomes statistically significant only from 2024 onward and that movements in interest rates do not account for this pattern.

Theoretically, this finding carries considerable weight. Read together, Brynjolfsson et al. (2025) and Autor (2024) reveal a tension. By making tacit knowledge easier to access, artificial intelligence raises the *productivity* of inexperienced workers; however, for that same reason, it may reduce *demand* for entry-level positions. Firms have less reason to employ novice workers if artificial intelligence can produce the output novices produce, and over the medium and long run this could create a serious problem for skill accumulation. If the step through which experience is acquired disappears, the future supply of experienced workers will also decline.

Adoption is itself unevenly distributed, and evidence on that point completes the picture. Drawing on Danish survey and administrative register data, Humlum and Vestergaard (2024) show that roughly half of workers report using ChatGPT, but women are 16 percentage points less likely than men to use it for work purposes. Adoption is tilted toward young, less experienced, but high-achieving workers who were *already earning more before ChatGPT was released*, a pattern that on their reading reinforces existing wage differentials rather than narrowing them.

5.4. The Labor Share, Superstar Firms, and Wage Inequality

The distributional effect of artificial intelligence has to be assessed alongside the long-run distributional trends of automation. Karabarbounis and Neiman (2014) identify a downward trend in the labor share in 42 of the 59 countries with at least fifteen years of data; among the 46 countries with a trend that is statistically significant at the 5 percent level, the trend is negative in 37, and the decline is observed in each of the world's four largest economies. Roughly half of the decline, on their accounting, is explained by the fall in the relative price of investment goods, a development attributed largely to computerization. This finding shows that the distributional effect of information technology is global in scale and long-run in character.

Autor et al. (2020) set out the micro mechanism behind the decline in the labor share. Drawing on U.S. Economic Census micro data from 1982 onward together with international data, they show that sales concentration within industries has increased and that the labor share has fallen most in the industries where concentration rose most. The aggregate decline in the labor share stems mainly not from within-firm declines but *from reallocation* toward “superstar” firms with low labor shares. The same pattern repeats internationally. De Loecker et al. (2020) calculate that over the same period average markups rose from 18 percent above marginal cost in 1980 to 67 percent above marginal cost today. That

increase stems exclusively from the sharp rise of high-markup firms and occurs largely within industries rather than between them.

On the wage inequality dimension, the most comprehensive quantification comes from Acemoğlu and Restrepo (2022), who show that an estimated 50 to 70 percent of the change in the between-group wage structure in the United States over the past forty years can be accounted for by automation-driven task displacement. Their framework accounts for much of the change in education-related wage differentials over the 1980–2016 period. Once general equilibrium effects are included, moreover, large increases in wage inequality can arise alongside only modest aggregate productivity gains, which is essentially the empirical counterpart of the phenomenon of "so-so automation."

In light of these findings, two opposing hypotheses emerge. Both concern the distributional effect of artificial intelligence. The *inequality-increasing hypothesis* predicts that artificial intelligence will deliver disproportionate gains to capital owners and to workers with complementary skills, and will strengthen the superstar firm dynamic; it will also lower the labor share further; in this vein, Acemoğlu (2025) argues that artificial intelligence will probably widen the gap between capital and labor income. The *inequality-reducing hypothesis*, drawing on the findings of Noy and Zhang (2023), Brynjolfsson et al. (2025), and Dell'Acqua et al. (2026), holds that artificial intelligence may narrow skill differentials by making tacit knowledge more accessible to low-performing workers. The available evidence indicates that the two hypotheses may hold simultaneously at different levels: Skill differentials *among workers* may narrow while differentials *between capital and labor* and *across firms* widen.

6. Price Stability, Monetary Policy, and Central Banking

6.1. The Direct Channels of Digitalization on Inflation

Digitalization's effect on inflation dynamics is of first-order importance for monetary policy. Three channels carry it. Relative prices of information technology products fall, e-commerce applies competitive pressure, and price-setting behavior itself changes.

Cavallo (2018) supplies the most direct evidence on price-setting behavior. At multichannel retailers, the monthly frequency of regular price changes rose from 15.43 percent in the 2008–2010 period to 27.39 percent in the 2014–2017 period, which implies a fall in implied price durations from 6.48 months to 3.65 months. For products also sold on Amazon, durations are approximately 20 percent shorter

than for products that are not. Pass-through coefficients register the same gain in flexibility: Gasoline price pass-through has an elasticity of 0.22 in the full sample but 0.28 among products exposed to Amazon competition, and exchange rate pass-through at a two-quarter horizon is 0.44 as against 0.32.

For monetary policy, this finding cuts in two directions. One is greater price flexibility. It may mean that the real effects of monetary policy weaken. The other, and the more important one, is that prices grow more sensitive to aggregate shocks, so cost shocks pass into inflation more rapidly and in a more synchronized fashion. That second mechanism, Cavallo (2018) argues, is the true content of the "Amazon effect." Rather than lowering inflation permanently, e-commerce raises its volatility and its responsiveness to shocks.

Turning to measurement: Over the 2014–2017 period, online inflation computed with the matched-model method ran more than one percentage point below the corresponding CPI categories, as Goolsbee and Klenow (2018) document. Allowing for new goods that enter and old ones that exit, true online inflation is estimated to be a further 1.5–2.5 percentage points lower. The finding indicates that official inflation measurement in the world of digital products may be upward biased.

Cross-country empirical evidence is more cautious. Csonto et al. (2019), working with panel data for the 2000–2017 period covering 36 advanced and developing economies, isolate a statistically significant and negative short-run effect of digitalization on inflation; that effect runs mainly through the cost and competition channel, and it has strengthened since 2012. Charbonneau et al. (2017), by contrast, call the contribution of information technology price effects to the CPI in the Canadian context "negligible," and argue that online and offline prices "behave remarkably similarly" and that disinflationary pressure has remained limited because of the small share of e-commerce in Canadian retailing. The caution is consistent with Cavallo's (2017) finding that online and in-store prices are identical in 72 percent of cases based on data from 56 large multichannel retailers in 10 countries.

Anderton et al. (2021) carried out a comprehensive assessment for the euro area. This European Central Bank expert working group puts the mechanical contribution of information technology product price declines to euro area Harmonised Index of Consumer Prices inflation at approximately 0.15 percentage points per year over a twenty-year period, where average inflation over the same period was 1.7%. The group calls the effect of e-commerce on inflation "small negative." The study also stresses that roughly one third of euro area employment is amenable to remote work and that digitalization-driven changes in price setting

and in the labor market "may lead to structural changes in the slope of the Phillips curve."

6.2. Market Structure, Markups, and the Flattening of the Phillips Curve

Market structure carries the indirect effect of digitalization on inflation, an effect that is, nonetheless, probably the more important one. Concentration and rising markups, discussed in earlier sections, have direct consequences for inflation dynamics.

In the model built by Andrés et al. (2026), growing market polarization and concentration lead large firms to optimally *dampen* their price response to cost shocks. Countercyclical markup behavior mechanically flattens the Phillips curve and accounts for the weak inflation–output comovement observed in recent years. The mechanism, they stress, works regardless of what causes output to fluctuate.

Fujiwara and Matsuyama (2026) arrive at the same conclusion in a New Keynesian model with endogenous firm entry. Rising market concentration raises markups and lowers the rate of pass-through, which "structurally reduces the slope of the Phillips curve." Entry-driven cost-push shocks, they further show, generate an "observational" flattening through omitted variable bias in estimated inflation–marginal cost relationships.

These two studies bear on the general argument advanced here in the following way. Digitalization affects inflation less through a direct decline in product prices than through a change, brought about by the transformation of market structure, in the *sensitivity of inflation to economic activity*. From the standpoint of monetary policy, that is a deeper problem. If the Phillips curve has flattened structurally, then the real activity cost required to control inflation has risen.

6.3. The Two-Sided Effect of Artificial Intelligence on Inflation

Artificial intelligence affects inflation in a way whose sign can change with the time horizon. Aldasoro et al. (2024) model this two-sidedness most systematically. In their multisector model, calibrated to the U.S. economy, the outcome depends critically on *whether the productivity gains are anticipated*. When the gains are unanticipated, inflation initially moves in a disinflationary direction; it becomes inflationary after approximately four years, and peaks about 0.75 percentage points above the baseline scenario. When the gains are

anticipated, by contrast, inflation rises immediately by more than two percentage points. Where the productivity gains directly affect consumption goods sectors, aggregate output rises to roughly 30 percent above the baseline scenario within the first decade.

This model's economic intuition is clear. On the supply side, artificial intelligence lowers unit costs, which is disinflationary, whereas on the demand side it raises current consumption and investment in anticipation of future income growth, which is inflationary. Which of the two dominates depends on how quickly expectations form and on the timing of investment.

Schnabel (2026) offers a recent assessment from a policymaker's perspective. The member of the Executive Board of the European Central Bank argues that "in the short run, artificial intelligence is more likely to be inflationary than disinflationary." Energy-intensive data center investment, together with semiconductor and skilled labor bottlenecks, supplies the grounds. She further notes that the adoption of artificial intelligence is "associated with task reallocation and productivity gains rather than with widespread employment losses," and that if the productivity gains materialize, the equilibrium real interest rate will rise endogenously. That last point bears directly on the estimation of the neutral rate of interest in monetary policy.

Working from three transmission channels, Lenzu (2026) frames the relationship between artificial intelligence and monetary policy. Through the *cyclical channel*, artificial intelligence alters how supply and demand shocks pass into prices even when conventional measures of slack remain unchanged. The *structural channel* covers shifts in potential output and in the natural rate of interest. The *financial stability channel*, in turn, combines the beneficial effect of improved credit allocation with the risk of "asset valuations driven by inflated expectations and model monoculture." Out of the combination of these channels comes an "artificial intelligence–specific stagflation risk": The configuration that would emerge if productivity expectations pulled investment and asset prices forward while realized productivity growth fell short of those expectations.

The Bank for International Settlements (BIS, 2024) provides a comprehensive synthesis for central banks. Its data on the speed of adoption are striking: ChatGPT reached one million users in less than a week, and approximately 50 percent of U.S. households used generative artificial intelligence tools in the past year. On the productivity dimension, the report records that users of GitHub Copilot complete more than twice as many projects per week and that novice programmers with access to a language model raise their productivity by 55 percent. In the financial sector, roughly 70 percent of firms globally use artificial

intelligence for cash flow forecasting, liquidity management, and fraud detection. Global spending on artificial intelligence exceeded $150 billion in 2023.

6.4. The Digitalization of Money, Central Bank Digital Currency, and Monetary Transmission

Digitalization affects macroeconomics along a separate dimension as well: Money itself is transformed. Brunnermeier et al. (2019) argue that digital innovation has produced an “unbundling” of the traditional functions of money and, in parallel, a “rebundling” of payments with data services through platforms. They warn that “digital dollarization” and cross-border “digital currency areas” may form in digitally and socially integrated regions, and they contend that a central bank digital currency “ensures that public money remains viable as a unit of account.”

Diffusion data on central bank digital currency (CBDC) indicate a rapid increase in institutional interest. Auer et al. (2020) record that, as of 2020, 80 percent of the central banks surveyed were engaged in CBDC research, experimentation, or development. By the 2023 survey, on which Di Iorio et al. (2024) draw, that share had risen to 94 percent; approximately 67 percent of responding jurisdictions had developed or were developing a regulatory framework for stablecoins or crypto assets. One trend stands out: Within the next six years, a wholesale CBDC is regarded as more likely to be issued than a retail CBDC.

Fernández-Villaverde et al. (2021) developed the theoretical framework for the macroeconomic consequences of a CBDC. Their central result is an equivalence theorem: As long as there are no bank panics, the set of allocations achieved through private financial intermediation can also be achieved with a CBDC. A CBDC's distinctive advantage is its stability during bank panics. By contrast, they draw attention to the risk of creating a “deposit monopoly” for the central bank and of weakening the maturity transformation function of private banks. The trade-off shows that CBDC design - whether or not it bears interest, holding limits, an intermediated structure- is decisive for macroeconomic outcomes.

6.5. The Transformation of Central Banks Themselves

Finally, what artificial intelligence does to the internal operation of central banks is attracting increasing attention. Kazinnik and Brynjolfsson (2025) estimate that approximately 25 percent of occupations in the U.S. Federal Reserve System display meaningful potential for artificial intelligence–driven productivity gains (5.8% very high and 18.3% high exposure). Across the System as a whole, an estimated 50–54 percent of staff hours -roughly 20–24 million hours- are calculated to be augmentable with generative artificial intelligence. The same study documents central bank applications already in place: The Hong Kong Monetary Authority's earnings call analysis tool, the European Central Bank's Athena and GABI supervisory tools, the Czech National Bank's language model–based inflation forecasting, and the Bundesbank's MILA statement analysis tool. This development may amount to a qualitative leap in the data processing and forecasting capacity of monetary policy institutions but it also gives rise to new risks such as model monoculture and the systemic propagation of algorithmic errors (Lenzu, 2026).

7. Public Finance, Taxation, and Measurement

7.1. The Capital–Labor Tax Asymmetry and the Automation Incentive

Automation's pace and direction are not a purely technological phenomenon; they also depend on the relative prices the tax system generates. Acemoğlu et al. (2020) supply the most powerful empirical demonstration of this insight: In their calculations from U.S. data, the effective tax rate on labor ranged between 25.5 percent and 33.5 percent over the 2010s, while equipment and software capital carried an effective rate of only about 10 percent. Following the 2017 tax reform, the rate on capital declined to approximately 5 percent.

That asymmetry carries macroeconomic consequences that are not trivial. The optimal tax structure they compute reverses the existing ordering: 18.22 percent on labor and 26.65 percent on capital. A move from the tax system of the 2010s to optimal capital and labor taxation would raise employment by 4.02 percent and the labor share by 0.78 percentage points, and even more modest and implementable reforms could raise employment by between 1.14 percent and 1.96 percent.

Conceptually, the finding separates “halting automation” from “not artificially encouraging automation.” Existing tax systems make capital investment

systematically cheaper than employing labor, and in doing so they render profitable even those forms of automation that deliver no productivity gains. Acemoğlu and Johnson's (2023) concept of "so-so automation" names precisely this phenomenon: Technologies that substitute for labor but bring no appreciable productivity gains spread only to the extent that the tax and regulatory framework make them artificially cheap. Building on this observation, Acemoğlu et al. (2023) propose a policy package that includes equalizing the taxation of labor and capital, public funding of human-complementary artificial intelligence research, and updating workplace surveillance rules.

7.2. The Robot Tax Debate

Taxing automation directly has attracted broad public attention. In the economics literature, however, the proposal has met with more measured results: Guerreiro et al. (2022) compute the optimal robot tax in a model that incorporates the displacement of a generation of workers employed in routine tasks. In their model the optimal robot tax is 5.1 percent for the decade beginning in 2018, 2.2 percent for the decade beginning in 2028, and 0.6 percent for the decade beginning in 2038, and it falls to *zero* once the displaced generation of routine workers retires. As matters stand, the effective tax rate on robots was 3.8 percent before the 2017 tax reform and declined to 1.8 percent after it. For the initial cohort of older routine workers, welfare gains reach as much as 2.2 percent of consumption, whereas the aggregate utilitarian welfare gain remains at 0.21 percent in consumption-equivalent terms.

For policy, the result means that the optimal robot tax is *positive but temporary*. Neither a permanent source of revenue nor an instrument for slowing technology, the tax is a device that shares the adjustment cost borne by the generation displaced during the transition.

Thuemmel (2023) reaches a more skeptical conclusion. He shows that distorting robot adoption -taxing or subsidizing it- in order to exploit general equilibrium wage compression effects may be optimal, but he concludes that the additional welfare gains from taxing robots *differently* from other equipment capital are "close to zero." Using a sufficient statistics approach, Costinot and Werning (2023) develop a general framework for technology regulation and obtain a counterintuitive comparative static result: As automation and globalization deepen and inequality rises, the optimal tax rate on robots and on trade *may fall*.

Across these three studies the same implication emerges: the robot tax is not a "magic wand." Removing the asymmetry that favors capital in the existing tax

system and redesigning the income tax and transfer system may deal with the distributional consequences of automation more effectively than taxing automation directly.

7.3. Competition Policy and the Direction of Technology

Competition policy is the third policy domain that shapes the macroeconomic consequences of artificial intelligence. Furman and Seamans (2019) compile the evidence on the scale of AI diffusion and situate the issue within a competition policy framework. The trends they document are notable. Worldwide robot shipments rose by roughly 150 percent over the period 2010–2016, and by roughly 100 percent in the United States. In 2016–2017, patent applications related to artificial intelligence reached roughly twice the annual average for 2002–2015, and academic publications on artificial intelligence have increased ninefold since 1996 -against a sixfold increase for computer science publications as a whole. Faced with these concentration trends, they assess options such as a regulatory agency specific to artificial intelligence, an expanded application of competition law, and income guarantee policies.

An important paradox turns up when Calvino and Criscuolo (2019) combine harmonized business dynamics data for fifteen countries with a measure of digital intensity. Digital-intensive sectors, and digital-intensive services in particular, are on average *more dynamic* than the rest of the economy; business dynamism is nevertheless declining in these sectors as well, and the decline is *sharper* than in other sectors, particularly after 2001. That pattern directly calls into question the assumption that digitalization will naturally produce a competitive market structure.

Acemoğlu (2023) addresses the question of the direction of technology more comprehensively. On its current path, he argues, AI development has the potential to harm competition, consumer privacy, and consumer choice; to fuel inequality by excessively automating work, to push wages down inefficiently, and to fail to improve worker productivity; and to damage political discourse and democracy. His critical argument is that these costs are *not inherent* to AI technology; they arise from how the technology is developed and deployed, that is, from an orientation toward “empowering corporations and governments against workers and citizens.” Promoting competition alone is, therefore, insufficient; regulation and policies that effectively redirect artificial intelligence research and development are required.

This observation coincides with a warning that the institutional economics tradition voiced much earlier. Drawing on a Schumpeter–Veblen synthesis, Dura and Güler (2022) conclude that technological change does not occur spontaneously either as progress articulated with social development, as in Veblen, or as a transformative form of creative destruction, as in Schumpeter. Institutional structures, in their account, are able to use expanding technical knowledge as a function that facilitates management and strengthens control; technological change then turns into an instrument that preserves the existing status quo rather than a factor that transforms the social structure. Where authoritarian political power has shaped institutional structures, they add, those structures tend to impose a static and relatively conservative social structure in place of the changes that a dynamic society brings. Countries in which the link between political power and institutional structure is relatively weak can, by contrast, act less ideologically in order not to obstruct the dynamism that creative destruction generates. Contract enforcement and intellectual property rights belong to the same framework. Both encourage innovative investment in the face of its irreversibility. Where the institutional structure is weak, financial underdevelopment and the absence of a contracting infrastructure make the new technological transformation that is to replace the old one more fragile.

In the context of artificial intelligence, this framework has a direct counterpart. Technology can be applied to expand the capacity for surveillance, control, and coordination, or it can be applied to raise productivity and human capability, and the choice between them is determined by the institutional framework rather than by the technology itself. Acemoğlu's (2023) warning about the orientation of artificial intelligence toward “empowering corporations and governments against workers and citizens” and Dura and Güler's (2022) observation that institutional structures can turn technical knowledge into an instrument of control arrive at the same conclusion from different theoretical traditions.

From a historical perspective, Bessen (2019) offers a more balanced picture. Two centuries of data on the textile, steel, and automotive industries in the United States show that automation initially *raised* employment in these sectors because product demand was highly elastic. Employment declined only after demand reached saturation. A simple model of demand elasticity explains why productivity-enhancing technology raises employment in some sectors while reducing it in others; automation, he concludes, is unlikely to lead to mass unemployment, but it will require disruptive worker transitions across sectors and occupations.

7.4. The Limits of National Income Accounting and the Policy Implication

The measurement problems discussed in earlier sections have two direct consequences for public policy. First, as the gap between the growth of welfare and the growth of measured output widens, GDP-based policy targets become misleading; the complementary measures that Brynjolfsson et al. (2019) and Nakamura et al. (2017) propose partially close this gap, but the official statistical system has not yet integrated them. Second, and more practically, national accounts underrecord intangible capital -particularly data capital, thereby systematically biasing estimates of the capital stock and, consequently, total factor productivity (Brynjolfsson et al., 2021; Bontadini et al., 2025).

This problem matters for policy because the debate over the productivity effect of artificial intelligence itself depends on the quality of the measurement framework. If the economy is in the first phase of the J-curve, the measured productivity slowdown may be a *symptom* of investment; if it is not, the same observation indicates that the technology promises less than expected. Telling the two interpretations apart requires measuring complementary intangible investment directly. Investment in the capacity of statistical agencies, therefore, becomes an indirect but genuine macroeconomic policy priority.

8. The Global Economy and Developing Economies

8.1. International Differences in Exposure and Readiness

Across countries, the macroeconomic effects of artificial intelligence are not homogeneous. Cazzaniga et al. (2024) quantify that heterogeneity most comprehensively; by their calculations, approximately 40 percent of global employment sits in “high-exposure” occupations. The average conceals a striking difference across country groups, however. In the average advanced economy, 27 percent of employment falls into the high-exposure, high-complementarity category and 33 percent into the high-exposure, low-complementarity category, so that total exposure runs to approximately 60 percent. Emerging markets record 16 percent and 24 percent, respectively -approximately 40% in total. The corresponding shares in low-income countries are 8 percent and 18 percent - approximately 26% in total.

This distribution can be read in two directions. Both readings are macroeconomically meaningful. On the one hand, low exposure implies less

displacement risk in the short run; the labor markets of developing economies may be better insulated against sudden shocks originating in artificial intelligence. On the other, that same low exposure means these economies will also benefit less from productivity gains. That asymmetry, the authors stress, creates the risk that income differences across countries will widen. Gmyrek et al. (2023) confirm the same pattern: Automation exposure in low-income countries runs at 0.4 percent and augmentation exposure at 10.4 percent, whereas the high-income shares are 5.5 percent and 13.4 percent. An updated study dated 2025 puts total exposure at 34 percent in high-income countries and 11 percent in low-income countries (Gmyrek et al., 2025).

Countries' *readiness* to benefit from this technology matters just as much as exposure. Covering 174 economies, the International Monetary Fund's Artificial Intelligence Preparedness Index (IMF, 2024) rests on four pillars: digital infrastructure, human capital and labor market policies, innovation and economic integration, and regulation and ethics. Singapore (0.80), Denmark (0.78), and the United States (0.77) hold the highest scores.

Data on how artificial intelligence resources are distributed worldwide make the scale of the gap concrete. Over the 2000–2024 period, high-income countries hosted 85 percent of artificial intelligence startups, 91 percent of artificial intelligence venture capital funding, and 54 percent of artificial intelligence publications (World Bank, 2025). More than 99 percent of ChatGPT traffic originates in high-income and upper-middle-income countries. The low-income share remains below 1 percent. A fixed broadband subscription costs 29 percent of monthly income in low-income countries, while in high-income countries the cost falls below 3 percent. The same report puts artificial intelligence adoption among OECD firms at only 8 percent as of 2024.

Investment is concentrated to a similar degree. Data from the Stanford Institute for Human-Centered Artificial Intelligence (2025) put global corporate artificial intelligence investment at $252.3 billion in 2024 -an annual increase of 25.5%- and generative artificial intelligence investment at $33.9 billion. Private artificial intelligence investment came to $109.1 billion in the United States and $9.3 billion in China. UNCTAD (2025) documents that roughly 100 companies, most of which are based in the United States and China, account for 40 percent of the world's private research and development investment, and that 118 countries, most of them in the Global South, take no part in global artificial intelligence governance discussions. The same report projects that the artificial intelligence market will reach $4.8 trillion by 2033.

8.2. Premature Deindustrialization and the Erosion of Comparative Advantage

For developing economies, the deepest macroeconomic risk from artificial intelligence is that it erodes the traditional foundation of development strategy. Rodrik (2016) framed this debate by documenting the phenomenon of "premature deindustrialization." The hump-shaped relationship between the manufacturing share and the level of income, he finds, *has shifted downward* relative to the early industrializers: Today's developing economies begin to deindustrialize at lower income levels and at lower peaks of the manufacturing share. Latin American countries have been affected particularly adversely, whereas Asian manufacturing exporters have been relatively insulated. He attributes the phenomenon to globalization combined with labor-saving technical change.

New technologies deepen this picture, and Rodrik (2018) traces the mechanisms through which this occurs. The mechanism he characterizes as a "double blow" works as follows. New technologies favor skilled-labor-intensive and capital-intensive production and thereby erode the traditional low-wage labor advantage of developing economies; at the same time, integration into global value chains reduces firms' ability to substitute cheap labor for other inputs. New capabilities and jobs, he concludes, "remain confined to a very small slice of globally integrated firms." Coming at the same phenomenon from a different angle, Baldwin (2019) develops the concept of "globotics," arguing that machine translation and telepresence technologies make it possible for foreign "telemigrants" to compete remotely with white-collar and service workers in rich countries.

Against this pessimistic framing stands evidence that automation may affect developing economies in more nuanced ways. In the estimates of Artuc et al. (2018), a 10-percentage point increase in robot density in advanced ("North") countries raises imports from developing ("South") countries by 6.1 percent, raises exports to those countries by 11.8 percent, and reduces the South's net imports from the North by 5.7 percent. Southern countries, the authors imply, can gain through cheaper and expanding trade even if they have not themselves adopted robots.

Comin and Mestieri (2018) pin down which dimension of technology diffusion is critical for development. Drawing on two centuries of data, the authors find *adoption lags* between rich and poor countries narrowing, but the *intensity with*

which adopted technologies are used diverging. In the nineteenth century, differences in adoption lags account for most of the income gap; from the twentieth century onward, differences in usage intensity account for most of the divergence. For artificial intelligence the implication is direct. The problem facing developing economies is not *access* to technology; it is the capacity *to apply technology widely and intensively* across the economy as a whole. That in turn carries the debate over complementary investment into the context of global development.

9. An Assessment for Türkiye

9.1. The State of Digitalization and Artificial Intelligence Adoption in Türkiye

Türkiye's digitalization performance differs markedly between the household dimension and the enterprise dimension. Indicators of individual digitalization converge strongly. The share of individuals who used the internet within the previous three months rose from 81.4 percent in 2021 to 89.8 percent in 2025 (Eurostat, 2025b). In long-run perspective the change is still more striking. From 13.3 percent in 2004, the share has risen roughly sevenfold over two decades.

Artificial intelligence adoption at the enterprise level, by contrast, lags markedly. Among enterprises with ten or more employees, the share in Türkiye using at least one artificial intelligence technology was 2.7 percent in 2021, 5.5 percent in 2023, 4.4 percent in 2024, and 7.4 percent in 2025. The European Union (EU) average over the same period rose from 7.7 percent (2021) to 20.0 percent (2025) (Eurostat, 2025a). Türkiye's 2025 rate sits close to the EU's 2021 level, which points to a lag of roughly four years. For comparison, Denmark stood at 42.0 percent in 2025 and Finland at 37.8 percent; the lowest rates within the European Union are found in Romania (5.2%), Poland (8.4%), and Bulgaria (8.6%).

On readiness to benefit from artificial intelligence, Türkiye occupies an intermediate position. Türkiye scores 0.540 on the International Monetary Fund's Artificial Intelligence Preparedness Index (IMF, 2024). That value falls markedly below those of leading economies such as Singapore (0.80), Denmark (0.78), and the United States (0.77), and sits in a range similar to that of countries such as Romania (0.584), Saudi Arabia (0.577), Russia (0.559), Uruguay (0.549), Thailand (0.536), and Mexico (0.532).

9.2. Firm-Level Evidence and the Policy Framework

Firm-level empirical work on the productivity effects of digitalization in Türkiye is limited. Among the available studies, Fazlıoğlu et al. (2026) examine the effect of broadband adoption on total factor productivity, using panel data on Turkish firms for the 2012–2015 period and an endogenous switching regression design. In the Turkish context, their findings directly support the general argument of this chapter. DSL connections produce no significant total factor productivity gain, whereas other fixed broadband technologies deliver productivity increases of 0.022 points in manufacturing and 0.117 points in services. Information and communication technology firms register the largest gains. Access to infrastructure alone, as the authors stress, does not guarantee a productivity gain; the Turkish evidence mirrors the findings of Bresnahan et al. (2002) and Bloom et al. (2012). Yüksel (2024) examines the artificial intelligence applications of manufacturing companies in Türkiye empirically, yet the Turkish-language and Türkiye-focused literature in this area remains relatively weak, and that gap is itself a research priority.

On the policy side, Türkiye has an artificial intelligence strategy at the national level. The National Artificial Intelligence Strategy (*Ulusal Yapay Zekâ Stratejisi*) was prepared in alignment with the Eleventh Development Plan (*On Birinci Kalkınma Planı*) and the Annual Presidential Programs (*Cumhurbaşkanlığı Yıllık Programları*) (OECD.AI, 2026). Its existence is a positive indicator for the building of institutional capacity. Even so, the adoption data reported above show that a considerable distance remains between the policy document and outcomes at the firm level.

9.3. Macroeconomic Implications and Policy Priorities

There are five areas of macroeconomic implication for Türkiye. First, the priority lies not in the production of technology but in widespread adoption. For developing economies, Comin and Mestieri (2018) locate the principal source of income divergence in differences in usage intensity rather than in the adoption lag. Türkiye's enterprise-level adoption rate (7.4%) stands at one-third of the European Union average (20.0%). This gap indicates that limited public resources should be directed less toward producing frontier technology than toward diffusing existing technologies to small and medium-sized enterprises. Within the EU itself, the gap between large enterprises (55.0%) and small enterprises (17.0%) shows that this priority is universal (Eurostat, 2025a).

Second, complementary investments are more decisive than the technology itself. Brynjolfsson and Hitt (2000), Bresnahan et al. (2002), Bloom et al. (2012), and, in the Turkish context, Fazlıoğlu et al. (2026) converge on the same conclusion: Investment in infrastructure and hardware does not translate into productivity unless organizational restructuring, management quality, and investment in skills accompany it. For Türkiye, that places the quality of management practices, the alignment of the vocational training system with digital skills, and in-firm training investment directly within the domain of macroeconomic productivity policy.

Third, sectoral structure limits the gains to be obtained from artificial intelligence. Productivity gains originating in artificial intelligence are tilted in favor of economies specialized in financial and information and communication services, and the gains of other G7 countries may be up to 50 percent lower (Filippucci et al., 2025). Given Türkiye's sectoral composition, short-run expectations should stay measured and the digitalization of service sectors should be defined as a priority. History supports that priority: van Ark et al. (2008) trace the principal source of the Europe–United States productivity gap to market services.

Fourth, labor market effects should be monitored as a change in composition. Dauth et al. (2021) and Acemoğlu and Restrepo (2020) reach different findings, which shows that the same technology produces different employment outcomes within different institutional frameworks. For Türkiye, what needs watching is the shift in the composition of tasks rather than the level of aggregate employment, and particularly the risk to entry-level employment documented by Brynjolfsson et al. (2025). In an economy where youth unemployment is structurally high, the erosion of the rung on which experience is acquired is a macroeconomically significant risk.

Fifth, measurement infrastructure is a policy priority. Because the national accounts undercount intangible capital and data capital (Brynjolfsson et al., 2021; Bontadini et al., 2025), productivity diagnoses are themselves unreliable. A regular, longitudinal micro-data infrastructure on firm-level digitalization and artificial intelligence use in Türkiye, open to researcher access, is a precondition both for evaluating policy and for developing the academic literature.

10. Conclusion

Along the line running from the information technology experience (Brynjolfsson & Hitt, 2000; Bresnahan et al., 2002; Bloom et al., 2012) to generative artificial intelligence (Brynjolfsson et al., 2021; Corrado et al., 2021; Bontadini et al., 2025), the findings are consistent: Whether technology translates into productivity depends on data infrastructure, organizational restructuring, worker training, and management quality. Each measured dollar of artificial intelligence investment may require between 2.7 and 4.1 times as much complementary intangible investment (Brynjolfsson et al., 2021). This is why a technological innovation takes so long to register in macroeconomic indicators. In the task-based framework, which begins with Autor et al. (2003) and which Acemoğlu and Restrepo (2018, 2019, 2022) later developed, the net employment effect of automation comes out of how displacement and reinstatement effects combine rather than out of the technology itself. In most cases artificial intelligence does not eliminate an entire occupation. It automates particular tasks, complements others, and creates new ones. The question “How many occupations are open to automation?” is, therefore, misspecified. Experiments and field studies show that generative artificial intelligence can raise both speed and quality in knowledge-intensive tasks (Noy & Zhang, 2023; Brynjolfsson et al., 2025; Dell'Acqua et al., 2026). The gains, however, vary fundamentally with the type of task, the worker's experience, and whether the task falls inside the technology's capability frontier. Outside that frontier, artificial intelligence assistance *can reduce* performance (Dell'Acqua et al., 2026). Calculations within the framework of Hulten's theorem put the ten-year gain in total factor productivity below 0.66 percent (Acemoğlu, 2025), whereas estimates built on analogies with general purpose technologies project annual increases of 0.8–1.3 percentage points (Aghion & Bunel, 2024). Organizational surveys point to widespread adoption alongside limited measurable financial impact (Baslandze et al., 2026; Singla et al., 2025). That divergence is the productivity paradox in its current form. A range this wide shows that the macroeconomic effect of artificial intelligence is less a forecasting problem than a *policy problem*. Even if artificial intelligence raises aggregate output, it may deepen wage inequality, the imbalance in the distribution between labor and capital, firm concentration, and regional disparities (Karabarbounis & Neiman, 2014; Autor et al., 2020; De Loecker et al., 2020; Acemoğlu & Restrepo, 2022; Acemoğlu, 2025). By contrast, to the extent that it makes tacit knowledge more accessible to inexperienced workers, the technology can also serve to narrow skill differentials. On the available evidence, the two tendencies may hold simultaneously at different levels: Skill differentials among workers may narrow while differences between capital and labor and differences among firms widen.

All five implications compiled above converge on one conclusion, and it confirms the argument set out in the introduction. Complementary investments, market structure, tax and competition policy, and the institutional framework will determine the macroeconomic future of artificial intelligence; the intrinsic properties of the technology will not. Technological progress, Acemoğlu and Johnson (2023) emphasize, does not automatically deliver widespread benefits to workers. That outcome requires countervailing institutional power. The institutional economics tradition has long defended that position, and this observation restates it in contemporary terms. From their Veblen–Schumpeter synthesis, Dura and Güler (2022) draw a conclusion in the same vein. Technological change takes place within an institutional structure, and depending on the character of that structure it may transform the status quo or preserve it. For macroeconomics as a discipline, that is an optimistic conclusion: The future is not a datum to be forecast but an outcome to be designed.

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From Globalization to Friend-Shoring? Geopolitical Alignment and U.S. Outward FDI to Emerging Economies

Assist. Prof. Şükran Kahveci Sürmeli[1,2]

Abstract

This chapter addresses that question using a panel of twenty emerging economies that together absorb the bulk of U.S. outward direct investment, observed annually from 2010 to 2024. Alignment is captured through ideal point distance, a measure derived from voting behaviors in the UN General Assembly. Estimation relies on a two-way fixed effects specification with Driscoll-Kraay standard errors, which accommodate the cross-sectional dependence, serial correlation and groupwise heteroskedasticity detected in the data. Interacting the alignment measure with indicators for successive presidential administrations allows its estimated effect to shift across periods rather than being pinned to a single average. Over the reference period, geopolitical distance depresses U.S. investment positions: the coefficient is negative and significant, and the elasticity is far from trivial. The picture changes thereafter. Total marginal effects computed for the Trump and Biden years retain the expected negative sign but fall short of conventional significance thresholds. Alignment, then, weighed less heavily on the allocation of American investment precisely when friend-shoring dominated policy discourse. That divergence between rhetoric and observed capital allocation sits uneasily with the empirical weight the friend-shoring hypothesis has acquired in recent scholarship.

Keywords: Foreign direct investment, geopolitical alignment, friend-shoring, ideal point distance, panel data analysis

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1. Introduction

The global financial crisis of 2008 marked a turning point for globalization. Hyper-globalization gave way to a slower, more hesitant process that observers came to label slowbalization. Recovery proved sluggish across the advanced economies, and as it dragged on, skepticisms toward global integration hardened. Arguments linking openness to widening income inequality gained traction in both scholarly and policy debate (Nissanke & Thorbecke, 2010; Rodrik, 2011; Milanovic, 2013). That skepticism translated into policy. Inward-looking agendas gathered momentum, and new barriers accumulated across trade, capital flows, migration, and technology transfer (Aiyar et al., 2023). A case in point is the United Kingdom's decision to exit the European Union in 2016, while the trade wars between the United States and China, the two largest economies in the world, represented a turning point that made protectionist tendencies evident and measurable (Alfaro, and Chor, 2023). Protectionist measures have been worsened by the Covid-19 pandemic. Restrictions introduced during the pandemic have increased the vulnerabilities of global trade. The Russia-Ukraine war has led to a geopolitical divide. Western sanctions against Russia and Belarus in support of Ukraine have caused significant disruptions in energy and agricultural commodity markets and trade barriers for these sectors (Gopinath, et al., 2025). Another driver of protectionism is the growing ambition of countries to dominate strategic industries of strategic importance, such as emerging technologies, artificial intelligence, renewable energy and biotechnology.

The world has had a turbulent period in economic, political and health terms since the Global Financial Crisis and this has had a major impact on the perspective on integration. The concept of geo-economic fragmentation (GEF), introduced into the literature by Aiyar et al. (2023), is an important phenomenon in the new economic order today. This idea is essentially expressed as a regression in integration and it is argued that this is not due to the natural working of the market mechanism, but to the conscious policy choices of governments. The authors argue that the motivation for geo-economic fragmentation is usually strategic concerns such as national security or economic autonomy, but sometimes the definition may include purely domestic policy goals. Several studies in this area have found that the direction of trade and investment flows between countries has changed and this may be a sign of geo-economic fragmentation (Aiyar et al., 2024; Catalan et al., 2024; Airaudo et al., 2025; Grover and Vézina, 2026).

In 2015 China launched the Made in China 2025 plan, which is a state-led industrial policy initiative to reduce external dependence in key sectors and achieve global industrial power. This initiative has identified the basic rationale

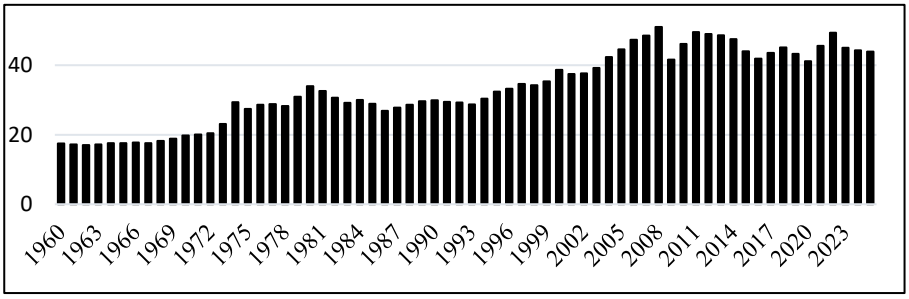
for the friend-shoring[3] and reshoring[4] strategies of Western countries (Maihold, 2022). US Treasury Secretary Janet Yellen in a speech in 2022 had argued that moving supply chains to a number of trusted countries rather than being overly reliant on countries facing geopolitical tensions would safely increase market access and reduce risks for the US economy and its trading partners. This discussion quickly took legal form, with the CHIPS and Science Act coming into force on August 9, 2022, and the Inflation Reduction Act (IRA), signed on August 16, 2022, and transformed into binding industrial policy instruments in the form of conditional targeted subsidies and tax incentives for domestic or allied production. In a letter dated January 9 (2023), the French government stressed the need for the EU to increase production targets, relax state aid rules, set up an emergency sovereignty fund and activate trade defense instruments in response to the US Inflation Reduction Act (Tamma and Stolton, 2023). This indicates that companies and policymakers are increasingly looking towards friend-shoring, nearshoring[5], and reshoring as a way to relocate production processes to reliable countries with converging political preferences and a low risk of conflict between countries in order to build supply chains that are more resilient to geopolitical tensions. The increasing focus on friend-shoring is a big departure from the traditional model of distributing production through offshoring (Aiyar et al., 2024).

While GEF and increased friend-shoring strategies may bring benefits to some countries, it is expected that they will have economic, social and environmental costs globally. This can also lower the level of living standards across the world, which would mostly affect consumers. This may be caused by the higher cost of imports, lower access to technology, lower access to labor (both skilled and unskilled) and lower productivity of manufacturing. Furthermore, the GEF could adversely affect the achievement of the climate change mitigation and sustainable development objectives. Indeed, the United States' withdrawal from the Paris Agreement in 2017 and 2025 demonstrates how geo-economic disintegration can undermine collective climate efforts (Haskett, 2025). The recent trends of slowdown of global trade and investment are a symptom of the economic impact of this geo-economic fragmentation phenomenon. The signs of this deceleration

[3] This is a strategy of directing supply chains to countries that share political and economic values and are considered geopolitically reliable, regardless of geographical proximity (Yellen, 2022).
[4] This is a strategy of bringing production activities that were previously moved abroad back within the borders of the investor country in order to increase supply security and reduce strategic dependence (Fratocchi et al. 2014).
[5] This is a strategy of shifting production activities to countries geographically close to the main market in order to reduce logistics costs and delivery times (Ellram et al., 2013).

are clear in the following graphs pertaining to trade openness (Figure 1) and FDI inflows (Figure 2).

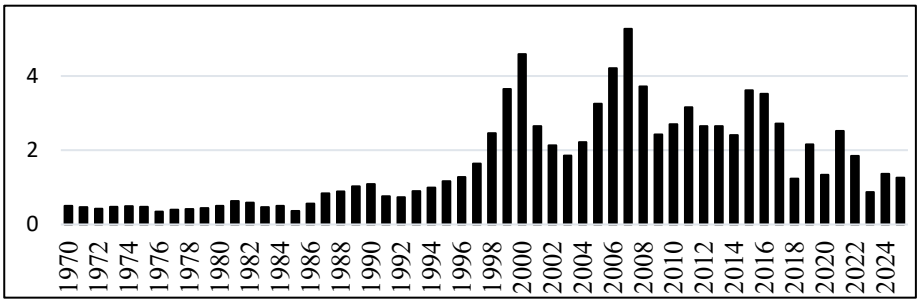
Figure 1. **Merchandise trade (% of GDP) (World)**



Source: World Bank Development Indicators (2026)

As shown in Figure 1, during the period of rapid globalization from the 1960s, the share of global merchandise trade in GDP has been steadily rising from about 15% to a historical high of 50.97% in 2008. The global financial crisis caused a steep decline, after which trade openness did not recover to pre-crisis levels and continued to decline throughout the 2010s. This period corresponds to what is known in the literature as "slowing globalization" (slowbalisation) and is the empirical basis for discussions of geo-economic fragmentation. The restrictions were lifted in 2020 due to the pandemic and the rate increased by 41% with a temporary surge in 2022. One could argue that the post-pandemic surge in demand, combined with the unprecedented rise in energy and commodity prices, caused the increase. Of course, the openness rate of trade declined again in 2023-2024 to the level of 43-44%. The recent downturn, which has coincided with the rise of friend-shoring and reshoring strategies, is a visual representation of the potential negative impacts of geo-economic fragmentation on global trade liberalization.

Figure 2. Foreign direct investment, net inflows (% of GDP) (World)



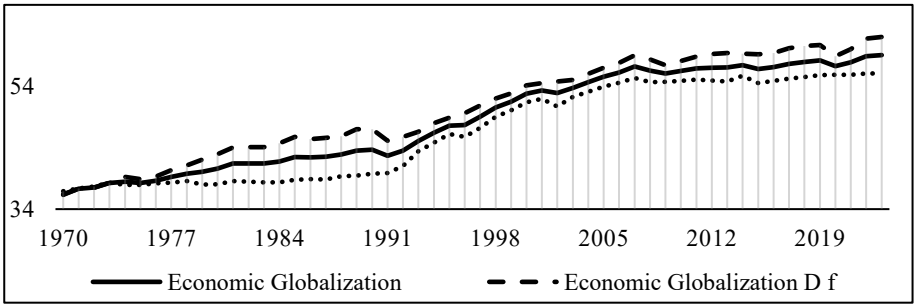
Source: World Bank Development Indicators (2026)

Figure 2 shows the persistent pattern of global net foreign direct investment (FDI) inflows relative to GDP, which provides strong support for the geo-economic fragmentation narrative. The increase from the 1970s to 2007, concurrent with the intensification of financial globalization, is indicative of a period of liberalization of capital mobility and reconfiguration of production networks by multinational corporations internationally. This process reached its peak in 2007 when the ratio went over 5% However, the sharp decline since the global financial crisis of 2008 and the bumpy horizontal trajectory in the following years suggest that global capital flows have not returned to their pre-crisis trajectory of expansion. As the chart shows, it is a steady, structural decline that began in 2017. The timing coincides with the growing US-China trade disputes, the rise of protectionist industrial measures, and the practice of "friend-shoring" and "nearshoring" for technology and supply chain security. In this case, the extra contraction caused by the 2020 pandemic shock and the emergence of geopolitical risks after 2022, bringing the ratio down significantly below its historical average, signals not just a cyclical variation by chance, but a fundamental shift, with global capital being increasingly reallocated along geopolitical alliance lines.

Economic globalization index is shown in Figure 3. This is another measure that might be indicative of geo-economic fragmentation. The graph shows the KOF Globalization Index, which was first developed by Dreher (2006) and updated by Gygli et al. (2019) so as to separate de facto and de jure dimensions. The graph shows the aggregate economic globalization sub-index, as well as its de facto and de jure dimensions. The de facto dimension of globalization is a measure of actual transnational flows (trade, investment, migration), while the de jure dimension measures the availability of legal and political structures governing these flows (tariff rates, treaties, capital controls, etc.). The sequences shown in the graph are

the overall, actual and legal scores calculated at the global average level of the KOF Economic Globalization Index, not at country level.

Figure 3. KOF Economic Globalization Index: Overall, De Facto, and De Jure Dimensions



Source: KOF Swiss Economic Institute (2026)

The fluctuation of the KOF Economic Globalization Index over the years seems to follow the trend of the FDI/GDP series. The index shows that global economic integration has reached a saturation point in terms of volume after 2008, having been on the rise up until 2008. Hyper-globalization evolved into what has come to be termed slowbalization. The widening of the gap between de facto and de jure elements during this period suggests that the slowdown in the rate of growth of integration may be due not only to situational factors, but also to a change in the fundamental dynamics. The current economic transactions (de facto) are overstepping the official regulatory framework (de jure) that guides them. This means that the current wave of protectionist or restrictive measures (GEF) has not yet been in line with real economic flows but this may change in the future.

The indicators of trade openness, foreign direct investment with respect to GDP and economic globalization show that the socio-economic dynamics after the global financial crisis have decelerated the pace of globalization. In recent years, the role of geo-economic fragmentation in the slowdown of globalization has been an ongoing debate. Reshoring is about countries bringing manufacturing back home to focus on home production, while friend-shoring is about changing trade and investment relations based on political proximity. As a result, both trends are changing the patterns of international trade and investment affecting not only the size but also the path and partners.

Concerning the background of the above discussion, this study aims to empirically investigate the effect of geo-economic fragmentation on foreign direct investment (FDI) flows. The preference of the United States as the object of analysis is determined by the tariff and trade policy pursued under the Trump administration and the industrial policy expressed in the regulations such as CHIPS, Science Act, and Inflation Reduction Act. They made the US a key player and the most obvious example of the phenomenon of geo-economic fragmentation. In this context, 20 countries that are major recipients of US direct investment were selected as a sample, and the impact of their geopolitical proximity on FDI inflows was examined. The structure of the research is as follows: The second section firstly analyzes the theoretical framework on traditional FDI determinants, secondly the role of geo-economic fragmentation among these determinants and the relevance of Geopolitical Distance Index (IPD) used to measure this phenomenon in the existent literature. The third section provides a systematic review of the relevant literature, emphasizing empirical evidence supporting the friend-shoring hypothesis, together with critical or dissenting views on the hypothesis. The fourth section presents the dataset and model used in the study. The fifth section discusses the econometric approach and empirical findings. Lastly, the sixth section concludes the research with findings and policy suggestions.

2. Determinants of FDI

2.1 Classical Determinants of FDI: The OLI Paradigm and the Gravity Model

Early concepts of FDI were based on the assumption that FDI is simply a movement of capital from one country to another. The assumptions were that capital moved from capital abundant countries with low returns to capital scarce countries with high returns (MacDougall, 1960). Hymer (1976) showed that this approach was not sufficient to explain the investment decisions of multinational corporations (MNCs) because the key factor was firm-specific advantages arising from imperfect competition. But Vernon's (1966) product cycle theory extended this firm-centered view to a time dimension, explaining post-war US FDI flows through the stages of innovation-maturity-decline (Denisia, 2010). Dunning (1997) combined these insights to develop the Eclectic paradigm (OLI), which assumes that multinational corporations should have ownership, location, and internalization advantages to guide their investment decisions (Latorre, 2014). Dunning (1988) expanded this framework by dividing ownership advantages into asset-based (O_a) and transaction-based (O_t) advantages and specified four major

motivations for FDI: market seeking, efficiency seeking, strategic asset seeking, and resource seeking. Dunning and Lundan (2008) added a third category to the OLI framework, institutional advantages (O_i), giving the most comprehensive interpretation of the paradigm to date. This expansion highlights a mutually beneficial relationship between the enterprise and the institutional and political environment of the host country, showing that firms not only adapt to the institutional setting, but also try to influence the institutional setting through political engagement. A thorough review of the literature on the determinants of FDI indicates the OLI paradigm as a key framework (da Cruz et al., 2022).

Additionally, the gravity model is another analytical instrument frequently employed in the empirical investigation of FDI determinants. The first to convert Newton's universal law of gravitation to the analysis of international trade was Jan Tinbergen (1962). That is, the economic size of two countries is directly proportional to their foreign trade and geographical distance is inversely proportional to their foreign trade. The first studies that applied this model to identify the determinants of FDI are those of Brainard (1993) and Eaton and Tamura (1994). The model predicts that the flows of foreign direct investment between two countries are proportional to the size of their economies and inversely proportional to the distance between them, the empirical equivalent of the location ("L") factor of the OLI framework. In recent empirical literature, besides basic indicators, advanced gravity models include factors like cultural proximity, infrastructure and institutional quality. The comprehensive shooting model provides, hence, an empirical testing ground for the organizational dimension (O_i) of the OLI framework of Dunning and Lundan (2008).

2.2. How Does Geoeconomic Fragmentation Affect FDI?

In the last few years, geopolitical factors have emerged as a major concern for investors, on par with economic risks and uncertainties. The greater the geopolitical distance between countries, the greater the uncertainty for investors about the future policy environment. The bigger the gap between the foreign policy stances of two countries, the higher the perceived risk of sudden sanctions, trade restrictions or diplomatic breakdowns between them (Julio and Yook, 2012). This implies significant risks for foreign direct investment involving large sunk costs. Investment choices are heavily influenced by prospective risks as well as current policies. These are mainly enforced restrictive measures, which are common especially between geopolitically distant countries. They include sanctions, export restrictions, tariffs, and investment screening mechanisms (e.g.,

CFIUS/FIRRMA in the US, FDI Screening Regulation in the EU) that deter investors (Alfaro and Chor, 2023).

From an institutional economics perspective, geographical proximity enhances contract security by means of mutual norms, values and institutional expectations among the parties involved (North, 1990; Williamson, 1975). Neighboring countries tend to have similar legal systems, property rights arrangements and conflict resolution processes. This reduces transaction costs and enhances investors' trust in the host country's institutional framework (Aiyar et al., 2024). This approach is a natural extension of the discussion on the benefits of institutional ownership (Oi) that Dunning and Lundan (2008) included in the OLI framework.

Thus, the effect of geo-economic fragmentation on foreign direct investment has emerged as an important area of investigation in recent years. To empirically test the effect of geo-economic fragmentation on foreign direct investment, however, one has to transform the geopolitical proximity or the distance between countries into a measurable variable. This is because GEF is not a single observable variable but a complex array of policy measures such as tariffs, sanctions and investment screening mechanisms. In academic parlance, the Ideal Point Distance (IPD) is a relevant proxy at the country-pair level that captures this complexity. IPD is mostly quantified through open voting (roll-call) records of the United Nations General Assembly (UNGA). Bailey et al. (2017) built a model that produces one-dimensional, temporally-extended "ideal point" estimates of nations using UN General Assembly voting data from 1946 to 2012. The main function of the IPD indicator is to produce quantitative metrics that capture countries' voting patterns and underlying foreign policy orientations. Each country is assumed to hold a specific position on a one-dimensional ideological axis. Each vote is assigned to one of three classes, acceptance, rejection or abstention, with two thresholds used to separate these three classes. In addition, each decision has a "decoupling parameter" that shows how well it separates countries on the geopolitical spectrum. Votes with strong decoupling power have a greater influence on the estimate, while decisions with near unanimity have a small impact. The ideal points are estimated by statistical methods and result in posterior means for each country-year. The geopolitical distance between two countries (Ideal Point Distance, IPD) is calculated as the absolute difference between their ideal points. The larger the IPD value, the greater the difference in foreign policy preferences between the two countries (Airaudo et al., 2025). The main explanatory variable in this study is IPD, which represents the geopolitical distance between the US and the 20 countries that are part of the data set and econometric model of chapter 4.

3. Literature Review

The effects of geo-economic fragmentation on global trade, foreign direct investment and portfolio flows have increasingly become the subject of an expanding empirical literature in recent years. The first part of this section discusses the studies that reveal the impact of geopolitical alignment on FDI flows. The second part of the section presents the studies that arrive at partially or completely contradictory conclusions.

One of the pioneering studies in this field, Aiyar et al. (2024), investigated the impact of geopolitical alignment on FDI flows by examining more than 300,000 greenfield FDI projects for the period 2003-2022. The result was tested by Grover and Vézina (2026) for three types of investment (greenfield, mergers and acquisitions and affiliate stocks) and four measures of geopolitical distance (bloc alignment, differences in liberal democracy indices, perceptions of public opinion and differences in UN voting). The study results provide further support for the robustness of the findings of Aiyar et al. (2024) by showing that the negative effect of geopolitical discord, especially on greenfield investments, doubled between 2011 and 2022.

These general sample findings are confirmed by country level studies. Kurul (2026) examined the outward foreign direct investment of Türkiye for the years of 2003-2023. The research results revealed that the Turkish outward foreign direct investment, especially in emerging markets, fell as the geopolitical distance increased, but powerful governance, especially in corruption control and accountability, mitigated this adverse effect. The research found that the effect of geopolitical alignment is strong in both the bilateral distance and the position in the US-China bloc, but the effect has been weakened after 2018. Similarly, Fletcher et al. (2024) investigate trends in Germany's FDI and find that FDI by Germany towards the China-Russia alliance is more responsive to the current geopolitical shifts than FDI towards the US alliance, and this sensitivity has increased over the last six years.

The literature also includes studies that describe the mechanisms behind these empirical observations. In their study of a territorial conflict between China and Japan, Chen et al. (2016) argued that the effects of a geopolitical shock on foreign direct investment may last much longer than the shock itself. The study suggests that the persistence of this effect is not due to real economic damage but rather a permanent change in the expectations and risk perceptions of firms. The phenomenon is not homogeneous across all companies and industries, and strong governance, better information access, and high R&D intensity in the host country largely reduce the negative impacts of geopolitical risk (Bussy and Zheng, 2023).

According to Heavilin and Songur (2017), besides geopolitics, cultural distance matters for FDI choices. Turkish Outward FDI provides an interesting paradox. As the cultural distance increases, the Turkish Outward Foreign Direct Investment (FDI) increases. This can be explained by the preference for FDI which has better control mechanisms, rather than exports.

The literature is expanding its focus from FDI to trade and portfolio flows, but this expansion displays considerable variation in channels. Countries that are far apart geopolitically trade less with each other and those whose economic progress depends on trading with geopolitical foes are especially vulnerable to the fragmentation, find Qiu et al. (2024). They claim that foreign direct investment stocks in geopolitically aligned countries reduce global welfare because geopolitical considerations override comparative advantage. Catalán et al. (2024) used the same logic for portfolio investment and showed that geopolitical distance has a strong negative effect on cross-border equity and bond holdings, but this effect is weaker in countries with high institutional quality. Airaudo et al. (2025) employ the same IPD indicator for trade, economic policy interventions and portfolio flows and find that large and convincing evidence of fragmentation is found only in the trade and policy areas. The effect on financial portfolio distributions is found to be much weaker, more varied and more sensitive to methodological choices. Abeliansky et al. (2024) add a component of this variability with a threshold effect. Empirical evidence suggests that the decline in FDI and portfolio investment is pronounced only with respect to "unfriendly" country pairs, whereas geopolitical differences between "friendly" countries do not significantly reduce investment. Finally, Gopinath et al. (2025) show that trade between competing blocs, foreign direct investment and portfolio movements have fallen substantially in post-war Ukraine compared to intra-bloc transactions, although this fragmentation is still modest compared to the Cold War era.

Additionally, there are studies in the literature that cast doubt on the effects of geopolitical fragmentation, demonstrating that the matter is still up for discussion. Alfaro and Chor (2023) show that the direct dependence of the US on China for supplies has fallen, but this dependence still exists to a large extent through indirect links to Vietnam and Mexico. Friend-shoring and reshoring have thus not yet achieved their objectives. Fajgelbaum and Khandelwal (2022) provide evidence for the idea that friend-shoring does not deliver the expected gains, showing that the static welfare cost of tariffs from the US-China trade war is fully passed through to consumers with no expected positive effects on employment. Jean (2024) argues that geo-economic fragmentation is limited to some "hot spots" such as Russia and US-China trade, and that trade realignment along

geopolitical blocs is not a common pattern. This finding directly contradicts the claim that geopolitical alignment is a universal determinant. Jakubik and Ruta (2023) also find that the effect of geopolitical distance on trade flows is not direct and significant, but rather the effect is observed only when there is an increase in global uncertainty. This suggests that geopolitical distance is important not by itself, but in conjunction with uncertainty. The results of Davis et al. (2019) suggest that the effect of geopolitical and political relations may differ significantly depending on country and ownership structure of the firm. Import choices of state-owned enterprises are significantly more influenced by political connections than those of private companies, and this is true for India's exports but not for China's. Thus, one could argue that the geopolitical effect is not a single "uniform" mechanism, but rather interacts with the specific institutional settings of each country.

The literature converges on the view that geopolitical alignment shapes FDI, trade and portfolio flows, yet agreement ends there. Estimates of how universal, how large and how durable that influence proves vary substantially across channels, country groups and time horizons. This chapter examines one channel and one source country: U.S. outward direct investment positions in twenty emerging economies, observed annually from 2010 to 2024. The United States is a natural starting point, both as the big investor in this group and as the state whose policy discourse has done most to define the friend-shoring agenda. Whereas existing work reads fragmentation off globally aggregated data, the analysis here allows the estimated effect of alignment to differ across presidential administrations, testing through period-interaction terms whether the influence of geopolitical distance strengthened or weakened as friend-shoring moved from rhetoric to declared policy.

4. Data and Model

This study estimates the impact of geopolitical alignment on US-originated FDI in a sample of 20 major developing countries receiving US foreign direct investment, using panel data analysis for the period 2010–2024. The sample consists of 20 countries classified as developing economies by the IMF and having a significant volume of US foreign direct investment. The countries were selected to ensure regional representation (Latin America, Asia, MENA, Sub-Saharan Africa, Central and Eastern Europe) and to cover a wide range of variation in terms of geopolitical alignment. The countries included in the sample are shown in Table 1.

Table 1. **Sample: 20 emerging economies included in the analysis of US outward FDI stocks**

Argentina	**Egypt**	**Morocco**	**Saudi Arabia**
Brazil	India	Nigeria	South Africa
Chile	Indonesia	Peru	Thailand
Colombia	Malaysia	Philippines	Türkiye
Czech Republic	Mexico	Poland	Vietnam

Two factors played a role in determining the analysis period as 2010–2024. First, the earliest date at which the IMF Coordinated Direct Investment Survey (CDIS) provides comparable and uninterrupted stock data for the countries in the sample coincides with the beginning of this period. Second, the period fully encompasses developments at the heart of discussions on geopolitical fragmentation (the post-2018 period of intensified trade tensions, pandemic-induced supply chain disruptions, and the years in which the friend-shoring discourse became prominent in the policy agenda).

The impact of geopolitical alignment on US-originated foreign direct investment is estimated using the following basic model, which includes country and year fixed effects:

$$lnFDI_{it} = \beta_0 + \beta_1 IPD_{i,t-1} + \beta_2 lnGDP_{it} + \beta_3 INF_{it} + \beta_4 TRAOP_{it} + \beta_5 RL_{it} + \beta_6 WUI_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (1)$$

In the formula, *i* is the country and *t* is the year. The dependent variable, FDI, is a measure of US position on outward direct investment in country *i*. The main explanatory variable, IPD, is a measure of the distance between the geopolitical ideal point of the US and that of country *i*. This variable is included in the model with a one period lag in order to alleviate the problem of endogeneity as a result of investment decisions responding simultaneously to political positioning. The direct investment position and gross domestic product are transformed in natural logarithm form. The inflation rate (INF), trade openness (TRAOP), rule of law index (RL) and World Uncertainty Index (WUI) are employed in linear form. In the model μ_i is unobservable country specific effects which are time-invariant, λ_t are year specific effects which reflect the global shocks affecting all countries and ε_{it} is the error term.

In order to test whether the effect of geopolitical alignment on investment decisions varies across presidential administrations, we added interaction terms between ideal point distance and temporal indicator variables to the basic model:

$$lnFDI_{it} = \beta_0 + \beta_1 IPD_{i,t-1} + \beta_2(IPD_{i,t-1} \times TRUMP_t) + \beta_3(IPD_{i,t-1} \times BIDEN_t) + \beta_4 lnGDP_{it} + \beta_5 INF_{it} + \beta_6 TRAOP_{it} + \beta_7 RL_{it} + \beta_8 WUI_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (2)$$

TRUMP and BIDEN are indicator variables that take the value 1 in 2017–2020 and 2021–2024, respectively, and 0 in other years; the reference category is the 2010–2016 period. These indicator variables are not included separately as main effects in the model because they are a linear combination of year-constant effects; the differences in levels between periods are controlled by λt. Interaction terms can be defined and estimated thanks to the variation of the ideal point distance between sections throughout the year.

In this context, the β_1 coefficient represents the direct impact of the ideal point distance on the investment position for the reference period (2010–2016). The β_2 and β_3 coefficients show the extent to which this effect differs during the Trump and Biden periods, respectively, compared to the reference period, they do not represent the total effect in their respective periods. Accordingly, the marginal impact of geopolitical alignment during the Trump period is given by the following sum, and the marginal impact during the Biden period is given by the second sum:

$$\beta_1 + \beta_2 \quad (3)$$

$$\beta_1 + \beta_3 \quad (4)$$

The key question in testing for the friend-shoring hypothesis is not so much the importance of the individual coefficients of interaction but whether the sums are statistically non-zero. Thus the sums were subject to linear constraint estimations,

and the marginal effects are shown in a separate panel in the corresponding table. In the estimations, Driscoll-Kraay standard errors were used, providing robust inference against cross-sectional dependence, autocorrelation, and heteroskedasticity problems commonly encountered in panel datasets. Table 2 describes the definitions of the variables used in the analyses, the units of measurement and the descriptions of the data sources.

Table 2. Variable Definitions and Data Sources

Variable	Definition / Description	Source
FDI	Outward foreign direct investment position (net, assets minus liabilities), all financial instruments and all institutional sectors included, in millions of US dollars.	IMF, Coordinated Direct Investment Survey (CDIS) Direction of Investment Positions
IPD	Ideal point distance between the partner country and the United States, lagged one period [IPD(partner–US), t–1]. A measure of geopolitical alignment (distance) based on UN General Assembly voting behaviour.	Bailey, Strezhnev & Voeten (2017), Ideal Point Distance data set
INF	Inflation rate, average consumer prices (index).	IMF, World Economic Outlook (WEO)
WUI	World Uncertainty Index; quarterly values annualised as simple annual averages.	Ahir, Bloom & Furceri (2022), "World Uncertainty Index", NBER Working Paper
GDP	Gross domestic product, constant 2015 US Dollars.	World Bank, World Development Indicators (WDI)
RL	Rule of Law index (indicator of institutional quality).	World Bank, Worldwide Governance Indicators (WGI)
TRAOP	Trade openness, total trade volume (exports + imports) as a percentage of GDP. For Nigeria, computed using ITC trade data and WDI current GDP.	World Bank, World Development Indicators (WDI); International Trade Centre (ITC)

Descriptive statistics for the variables are presented in Table 3.

Table 3. Descriptive Statistics

Variables	Average	Standard Deviation	Min	Max
Ln FDI	9.2084	1.1914	5.7652	11.9780
IPD	2.7158	0.6088	0.9830	3.8469
INF	7.9301	17.2391	-2.093	219.885
WUI	0.2537	0.2138	0.000	1.3429
RL	-0.1896	0.5414	-1.1859	1.2298
TRAOP	70.5757	39.5884	14.4292	186.6758
ln GDP	26.8639	0.7691	25.2338	28.8648

Table 3 shows that the geopolitical alignment variable is spread across a wide range (0.98–3.85) throughout the sample, indicating that the variation criterion considered in country selection is met. The distribution of logarithmic values of the direct investment position also reveals significant scale differences between countries. The inflation variable, however, exhibits a significantly skewed distribution; while the mean is 7.93, the series contains extreme values reaching 219.9, stemming from the high inflation experienced by some countries in the sample during the analysis period. The impact of these extreme values on the estimation results was also tested in the robustness analyses. The negative mean of the rule of law index (−0.19) reflects that the sample is positioned below the global average in terms of institutional quality.

5. Methodology and Empirical Findings

In this study, the presence of multicollinearity among the explanatory variables was first examined using the variance inflation factor (VIF). Then, the presence of cross-sectional dependence, which directly determines estimator selection in panel datasets, was tested using the CD test developed by Pesaran (2004). The preference between fixed effects and random effects models was evaluated using the Hausman (1978) specification test. Finally, the classical assumptions of the model were tested; the presence of autocorrelation was examined using the Wooldridge (2002) test, and the presence of heteroskedasticity between groups was examined using the modified Wald test proposed by Greene (2000). Since the diagnostic test results indicated the simultaneous presence of autocorrelation, heteroskedasticity between groups, and cross-sectional dependence in the model,

the model was estimated using robust standard errors developed by Driscoll and Kraay (1998) and adapted by Hoechle (2007) to the panel fixed effects estimator.

Before proceeding to the estimation stage, the variance inflation factor (VIF) was employed to check for multicollinearity among the independent variables. The obtained values are presented in Table 4.

Table 4. Variance Inflation Factors

Variable	VIF	1/VIF
RL	1.60	0.6258
TRAOP	1.50	0.6678
IPD	1.39	0.7180
lnGDP	1.19	0.8433
WUI	1.12	0.8939
INF	1.11	0.9132
Mean VIF	**1.31**	—

The variance inflation factor measures the extent to which one explanatory variable is explained by other explanatory variables, and high values indicate that the standard errors of the coefficient estimates are inflated. In applied literature, a value of 10 is considered the critical threshold. According to the findings in Table 4, the highest VIF value is 1.60, and the average VIF value is 1.31. These results show that there is no serious multicollinearity problem in the model and that the coefficient estimates can be reliably interpreted.

In panel data analysis, the first factor that directly determines the choice of estimator and unit root test is the presence of cross-sectional dependence. The results of the Pesaran CD test applied in this regard are presented in Table 5.

Table 5. Cross-Sectional Dependence Test (Pesaran CD)

Variable	CD-test	p-value
lnFDI	2.57	0.010
IPD	33.33	0.000
lnGDP	45.28	0.000
INF	14.98	0.000
TRAOP	11.11	0.000
WUI	1.95	0.051

Note: H0 = cross-sectional independence.

Globalization and financial integration have led countries to respond collectively to common shocks, leading to pervasive cross-sectional dependence in panel data sets. The neglect of this dependency induces inconsistencies in the conventional panel estimators. Therefore, in this study, the Pesaran (2004) CD test was preferred as it provides reliable results with panels where the cross-sectional units are more than the time periods. Table 5 shows that the null hypothesis of cross-sectional independence is rejected at 1% significance level for all series except for the WUI variable. The average correlation coefficients of 0.848 and 0.624 in the datasets of gross domestic product and geopolitical alignment respectively show that the countries in the sample react coherently to global shocks. This outcome requires the use of standard errors that are robust to cross-sectional dependence.

Diagnostic tests were conducted to determine the appropriate estimator and to test classical assumptions regarding model selection; the results are summarized in Table 6.

Table 6. Model Selection and Diagnostic Tests

Test	Statistic	df	p-value
Hausman (FE vs. RE)	$\chi^2 = 8.66$	8	0.372
Wooldridge AR(1)	F = 27.037	(1, 19)	0.000
Modified Wald	$\chi^2 = 266.52$	20	0.000

Note: H0 for the Hausman test = the random effects estimator is consistent; H0 for the Wooldridge test = no first-order autocorrelation; H0 for the Modified Wald test = groupwise homoskedasticity.

Hausman specification test (1978) was employed to compare fixed effects and random effects models. The test statistic was 8.66 (p = .372), and we could not reject the null hypothesis that the random effects estimator is consistent. The analysis continued with the use of a fixed effects model. The preference for this is due to three reasons: the sample is not randomly selected, but deliberately picked; geopolitical alignment is likely to be linked to country-specific and stable geographical, historical and institutional factors; and Driscoll-Kraay robust standard errors can be applied in the case of fixed effects. Furthermore, the fixed effects estimator yields consistent estimates irrespective of the correlation of the unit effects with the explanatory variables, while the random effects estimator is consistent only when there is no correlation (Wooldridge, 2010; Baltagi, 2021).

The Wooldridge (2002) autocorrelation test and the modified Wald test suggested by Greene (2000) were used to test the traditional assumptions of the model. The results of the Wooldridge test rejected the null hypothesis of no first-order autocorrelation (F = 27.037; $p < 0.01$) and the results of the modified Wald test rejected the null hypothesis of intergroup homoskedasticity ($\chi 2 = 266.52$; $p < 0.01$). So in addition to the cross-sectional dependence discussed in Table 5, it is also recognized that the model suffers from autocorrelation and intergroup heteroskedasticity. The model was estimated with robust standard errors (Driscoll and Kraay, 1998, adapted for fixed effects by Hoechle, 2007) to deal with these three problems simultaneously. Results for the fixed effects model computed using Driscoll-Kraay robust standard errors are presented in Table 7.

Table 7. Fixed-Effects Estimation Results with Driscoll-Kraay Standard Errors

Variable	Coef.	Std. Err.	t	p-value
IPD (t−1)	−0.1901**	0.0683	−2.78	0.012
IPD (t−1) × TRUMP	0.1023**	0.0384	2.67	0.015
IPD (t−1) × BIDEN	0.0840**	0.0361	2.33	0.031
lnGDP	0.8152***	0.0968	8.42	0.000
INF	−0.0006	0.0004	−1.65	0.116
TRAOP	0.0044***	0.0006	7.02	0.000
WUI	0.0428	0.0672	0.64	0.532
Constant	−12.4176***	2.6675	−4.66	0.000
Country fixed effects	Yes			
Year fixed effects	Yes			
Observations	300			
Number of countries	20			
F (21, 19)	4179.56			
Prob > F	0.000			
Within R^2	0.3234			
Maximum lag	2			

Note: *** p < 0.01, ** p < 0.05, * p < 0.10.

Findings shown in Table 7 indicate the coefficient for the variable of geopolitical alignment is negatively significant ($\beta_1 = 0.1901$, $p = 0.012$). Thus, a one-unit increase in the ideal point distance between the United States and the host country during the reference period (2010–2016) is associated with an estimated 19% decrease in the direct investment position. The result is consistent with the expectation that political proximity matters for investment decisions.

The coefficients of the interaction term are also positive and statistically significant during the Trump and Biden administrations ($\beta2 = 0.1023$; $p = 0.015$ and $\beta3 = 0.0840$; $p = 0.031$). These coefficients indicate that the detrimental effect of geopolitical distance on investments was significantly lower in both time periods compared to the baseline period. The significance of this finding is that the impact of geopolitical alignment on the distribution of investment weakens in times when the idea of friend-shoring is widely debated in policy circles.

The results regarding the control variables are consistent with the expectations of the literature on the determinants of traditional FDI flows. The coefficient for market size is positive and highly significant (0.8152; $p < 0.01$), indicating that a 1% increase in host country income increases the direct investment position by approximately 0.82%. Trade openness also positively affects investment, as expected (0.0044; $p < 0.01$). In contrast, the coefficients for inflation and global uncertainty variables were not statistically significant; the insignificance of uncertainty can be explained by the absorption of common global shocks by the year-fixed effects included in the model.

Since the coefficients of the interaction terms alone do not express the total effect in the relevant periods, the marginal effect of geopolitical alignment for each period was calculated using linear constraint tests, and the results are presented in Table 8.

Table 8. Marginal Effects of Geopolitical Alignment by Presidential Period

Period	Marginal effect	Std. Err.	t	p-value	95% CI
2010–2016 (reference): β_1	−0.1901	0.0683	−2.78	0.012	[−0.334; −0.047]
Trump (2017–2020): $\beta_1+\beta_2$	−0.0878	0.0733	−1.20	0.246	[−0.241; 0.066]
Biden (2021–2024): $\beta_1+\beta_3$	−0.1061	0.0642	−1.65	0.115	[−0.241; 0.028]

In order to properly estimate conditional marginal effects in interactive models, it is necessary to evaluate linear constraints by calculating the standard error of the sum of relevant coefficients by taking into account the covariance between variables (Brambor, Clark & Golder, 2006). The results in Table 8 indicate that

the effect of geopolitical alignment on the direct investment position is statistically significant only in the reference period (−0.1901; p = 0.012). The total marginal effect was −0.0878 (p = 0.246) under the Trump administration and −0.1061 (p = 0.115) under the Biden administration. In both cases, the effect is negative as expected, but not statistically significant.

Taken together, these results suggest that the driver of geopolitical alignment in the context of the geographical distribution of US-originated direct investment is weakening, not strengthening, during times of increased friend-shoring rhetoric. This result differs from international studies indicating that geopolitical fragmentation changes investment patterns along the lines of alignment. This result also shows that the friend-shoring theory regarding US-based investment is not as strongly supported by empirical evidence as previously suggested in the academic literature.

6. Conclusion

This research aims to examine the role of geopolitics in shaping the spatial pattern of U.S. foreign direct investment. The analysis was conducted using Driscoll-Kraay robust standard errors model on panel data of 20 major developing countries that received US investment from 2010 to 2024. Geopolitical alignment is measured by the ideal point distance (IPD) between voting patterns in the UN General Assembly. This variable was interacted with indicator variables for presidential terms to see whether the effect of alignment on investment choices changed across periods.

The results show that geopolitical alignment is an important determinant of the distribution of US-origin investment in the 2010–2016 period. During this period, a one-unit increase in the optimal point distance is associated with about a 19% decrease in the foreign direct investment ranking. For the interaction terms' coefficients, however, they were positive and significant for both the Trump and Biden administrations. The overall marginal effects computed for both periods were negative as expected, but not statistically significant.

The main finding of the study is that the influence of geopolitical alignment on the distribution of investment has weakened, not strengthened, in periods when friend-shoring was prominently discussed in policy debates. This finding contrasts with international research (Aiyar et al., 2024; Abeliansky et al., 2024; Airaudo et al., 2025; Catalán et al., 2024; Gopinath et al., 2025; Grover and Vézina, 2026), which states that the geopolitical fragmentation influences capital flows according to the alignment criteria. This is especially attributable to the

Trump administration's transition to a more transactional and dual-minded approach to foreign relations. The investment decisions seem to be based more on bilateral conversations and short-term self-interest calculations than on consensus within the multilateral organizations (UN), which diminishes the explanatory power of the geopolitical distance in this period. Friend-shoring has entered the policy discussion, but has not yet entered corporate settlement decisions in a consistent manner. Our results are consistent with the literature that places doubt on the effect of geo-economic fragmentation on investment and trade decisions (Davis, et al., 2019; Alfaro and Chor 2023; Fajgelbaum and Khandelwal 2022). The results for control variables are consistent with the theoretical model, where market size and trade liberalization remain important factors for investment.

The study has several limitations. First, the analysis period is limited to 15 years, with the last two presidential terms being relatively short sub-periods; this leads to wider confidence intervals for marginal effects and leaves open the question of whether the resulting insignificance stems from the absence of an effect or from limited estimation accuracy. Second, since the analysis is based on aggregated investment position data, differentiation between sectors cannot be observed; the alignment effect might be expected to be stronger in strategic sectors such as semiconductors and critical minerals. Finally, the findings are limited to US-originated investment and cannot be generalized to other investor countries.

These limitations present an agenda for future studies. First, using sector-specific disaggregated data would allow for testing whether friend-shoring is a phenomenon specific to certain strategic areas rather than the economy as a whole. Second, expanding the analysis to include investment from China and the European Union would allow for a comparative examination of the reciprocal repositioning dynamics of geopolitical fragmentation. Furthermore, testing whether these findings are specific to the US is an important agenda item for future research. The significant divergence in the US relationship with the UN and multilateral institutions during the Trump and Biden administrations compared to other G7 members has led to the IPD losing its explanatory power for the US.

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An Assessment Of Turkey's Sectoral Emission Trends For The 1970–2024 Period

Öznur TAŞDÖKEN [1]

Abstract

This study examines sectoral carbon emission trends in Turkey during the 1970–2024 period. In this context, the energy industry, transportation, industrial fuel combustion, buildings, industrial processes, fuel extraction, agriculture, and waste sectors are considered. Sectoral emission changes are evaluated using indicators such as absolute change, total percentage change, CAGR, AAGR, sectoral share, and contribution to the total increase. The findings show that Turkey's long-term increase in emissions is mainly concentrated in the energy industry, transportation, industrial fuel combustion, buildings, and industrial processes sectors. While the energy industry made the highest contribution to the total increase, the transportation sector became an important source of emissions, particularly in the post-2020 period. The results reveal that Turkey's climate policies require a sector-based, measurable transformation approach that also takes macroeconomic effects into account.

1.Introduction

Climate change has today become a strategic policy area with multidimensional consequences for economic growth, energy supply security, production structure, foreign trade balance, public finance, financial stability, and social welfare. At the global level, reducing carbon emissions, transitioning to low-carbon production models, increasing energy efficiency, and expanding renewable energy investments are among countries' sustainable development policies. Therefore, it is necessary to identify the sectors that cause increases in carbon emissions.

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Identifying these sectors is important for the preparation and implementation of climate policies.

Sector-based carbon emission analyses reveal the main structural dynamics that lead to increases in countries' emissions. Emission trends in sectors such as energy production, transportation, industry, buildings, agriculture, and waste are closely related to economic growth, energy consumption structure, technological capacity, urbanization, level of industrialization, transportation infrastructure, and the institutional policy framework. Therefore, it is not possible to implement carbon reduction policies in the same order of priority in every country. Since countries differ in terms of economic structure, energy supply structure, and sectoral growth trends, climate policies need to be developed and implemented on the basis of country-specific sectoral priorities.

During the 1970–2024 period, the Turkish economy underwent a significant process of economic and socio-cultural structural change, together with industrialization, urbanization, increasing energy demand, the expansion of transportation activities, growth in the building stock, and transformation in the production structure. This process led to an increase in carbon emissions resulted from the use of fossil fuel across sectors. Therefore, Turkey's long-term emission trends should be evaluated not only through total emission levels, but also through sectoral shares, periodic growth rates, contributions to the total increase, and sectoral breaks.

The main objective of this study is to systematically analyze Turkey's sectoral emission trends and current situation during the 1970–2024 period. Accordingly, it aims to reveal the areas of macroeconomic transformation needed from the perspective of climate policies based on the analysis results. Drawing on past emission performance, the study emphasizes the importance of green transformation in carbon-intensive sectors.

2.Previous Period Studies

Studies in the literature examining sector-based carbon emissions show that when evaluated through different methods and country examples, policies aimed at emission reduction produce different outcomes depending on the structural characteristics of different sectors. However, in general, the findings of these studies indicate that policies implemented across different sectors reduce carbon emissions. Nevertheless, these practices vary across countries. The effectiveness of these policies depends on factors such as countries' economic structure, energy supply structure, level of industrialization, technological capacity, transportation

infrastructure, urbanization dynamics, financing opportunities, and institutional policy framework.

In policies to be developed by policymakers for reducing carbon emissions, country-specific sectoral priorities, sectoral structures, and economic dynamics need to be identified. Since each country differs in terms of production structure, energy consumption profile, level of external dependence, sectoral growth trends, and capacity to adapt to climate policies, the order of priority of policy instruments to be implemented also varies. For Turkey, the primary step is to identify the sectors that drive the increase in carbon emissions and to analyze the long-term emission trends of these sectors in detail.

Identifying the sectoral sources of carbon emissions in Turkey will contribute to the development of measurable and applicable climate policies. Determining the sectors leading the increase in emissions will provide a scientific basis for establishing policy priorities.

Table 1: Previous Studies

Studies	**Country**	**Method**	**Years**	**Contribution of the Study**
Saboori et al., (2014)	27 OECD country	The Fully Modified Ordinary Least Squares (FM-OLS)	1960-2008	It shows that energy consumption in the transportation sector has a significant impact on both economic growth and carbon emissions.
Güzel & Alp, (2020)	Türkiye	The Integrated MARKAL-EFOM System (TIMES)	2016-2050	The transportation sector in Istanbul is examined, and the effects of different scenario applications on reducing greenhouse gas emissions were analyzed.
Abbes, (2021)	Eastern Europe	The logarithmic mean Divisia index (LMDI)	2005-2015	It evaluates the factors affecting transportation-related carbon emissions.
Everest, (2021)	Türkiye	Questionnaires	-	It has been observed that education, financing, technical support, and institutional guidance mechanisms are decisive in the expansion of climate-friendly agricultural practices.
Coşgun, (2021)	Türkiye	Analysis	-	Agrivoltaic systems have potential in terms of energy generation in

				agricultural areas, land-use efficiency, and emission reduction.
Isik et al., (2021)	Türkiye	The logarithmic mean Divisia index (LMDI)	2005-2018	It analyzes Turkey's energy sector by examining the relationships and dynamic structure between sectoral emissions and the main factors affecting these emissions.
Li et al., (2023)	China	The thematic analysis	-	The study evaluates decarbonization strategies in China's transportation sector.
Liu et al., (2024)	China	The generalized Divisia index method (GDIM)	2005-2022	It shows that, in transportation emissions, the scale of economic output had an increasing effect, while carbon intensity had a reducing effect.
Ali & Mujahid, (2024)	Pakistan	STIRPAT and ARDL	1971-2024	It analyzes the relationship between sectoral emissions and indicators of economic growth, population growth, and energy consumption.
Kazar, (2024)	Türkiye	NARDL	1960-2018	The asymmetric relationship between emissions generated in different sectors, sectoral value added, per capita income, and human capital is examined. In this framework, the years 1960–2014 are analyzed for the industry and services sectors, while the years 1970–2018 are analyzed for the agriculture sector.
Hou et al., (2025)	China	The Low Emissions Analysis Platform (LEAP),	2001-2022	It examines carbon emission patterns and emission peak pathways in China's industrial sector.
Shang et al., (2025)	China	The LandGEM model	2018-2022	It examines methane production patterns, determining factors, and mitigation potential in the waste sector.
Inam et al., (2025)	Country comparison	Feedforward Neural Network (FFNN), Times series Analysis	2024-2026	It presents a machine learning approach for predicting pollution and carbon emission trends in the industrial and electricity sectors.

Source: Prepared by the author.

Table 1 presents studies in the literature related to carbon intensity. The majority of studies in the literature have focused on Asian countries such as China, India, and Indonesia, as well as developed economies such as Europe and the United States. In these studies, methods such as LMDI (Logarithmic Mean Divisia Index), structural decomposition analysis (SDA/IDA), input-output analyses, panel econometrics, and hybrid models such as ARDL, Tapio decoupling, and IO-MRIO have been widely used. Studies focusing on Turkey generally use LMDI or econometric approaches in the industry, agriculture, and energy sectors, while methods such as life cycle analysis or machine learning are not commonly encountered in the literature. Comparatively, while there are numerous decomposition studies on energy-intensive sectors in Asia and Africa, such studies are more limited in Latin America and small economies. This general overview indicates the need to evaluate regional differences and methodological diversity in policies aimed at reducing sectoral carbon intensity.

Considering the studies in the literature focusing specifically on Turkey, electricity, transportation, and manufacturing are the most frequently examined sectors, while there are fewer studies on sectors such as services or waste. In general, all studies emphasize that energy efficiency and renewable energy integration are key elements in emission reduction in Turkey. From a policy perspective, structural measures such as renewable energy incentives, carbon pricing, and new emission standards come to the fore. In particular, moving away from coal and increasing the share of renewables in the electricity sector, as well as demand management policies in transportation, are identified as critical.

3. General Overview of Greenhouse Gas Emissions in Turkey

3.1. Calculation Method

In the study, the 1970–2024 period was divided into sub-periods in order to analyze different sectoral emission intensities. The periods 1970–1979, 1980–1989, 1990–1999, 2000–2009, and 2010–2019 were determined as the analysis intervals. These periods make it possible to track long-term trends through periodic differences. They also reveal more clearly how the weight of different sectors within the total emissions structure has changed over time. The sectoral classification used in the carbon emission analysis was defined by considering the main sector classifications included in the IPCC greenhouse gas inventory methodology (See. Table 2). The data used in the study were obtained from the *GHG Emissions of All World Countries* report (Crippa M., et.all, 2025).

Table 2: Sector Definitions

Sector	Definition
Energy Industry	It includes fuel combustion emissions arising from electricity and heat generation, petroleum refining, solid fuel production, and energy transformation activities. This sector includes emissions of CO_2, as well as CH_4 and N_2O, resulting from the combustion of fossil fuels for electricity and heat generation.
Industrial Fuel Combustion / Industrial Combustion	It refers to emissions resulting from the combustion of fossil fuels used in manufacturing industry and construction activities. It considers CO_2 emissions generated by the combustion of fuels used for energy production or the heating process of iron, steel, chemicals, cement, food, textiles, non-metallic minerals, and other manufacturing activities.
Transportation	It includes emissions resulting from the combustion of fuels used in road transport, rail transport, domestic aviation, domestic maritime transport, and pipeline transportation.
Buildings	It includes emissions resulted from fuels used for heating, cooling, hot water, cooking, lighting, and other energy services in residential, commercial, and institutional buildings.
Fuel Extraction / Operation	It includes fugitive or unintended emissions arising during the extraction, processing, storage, transportation, and distribution of fossil fuels. Solid fuel mining, oil and natural gas production, non-refinery processing, pipeline transportation, storage, and distribution processes are considered within this scope.
Industrial Processes	It includes emissions arising not from the combustion of fuel for energy purposes, but from chemical or physical transformations in the production process.
Agriculture	It includes greenhouse gas emissions resulting from agricultural production activities.
Waste	It includes emissions arising from solid waste disposal, biological treatment of waste, waste incineration or open burning, and wastewater treatment and discharge.

Source: Prepared by the author.

Table 3: Methods Used in the Analysis

Calculation	**Formula Used**	**Explanation**
Absolute change	$\Delta E_s = E_{s,2024} - E_{s,1970}$	It provides the absolute increase/decrease in sectoral emissions during the 1970–2024 period.
Total percentage change	$\%\,\Delta E_s = \left(\frac{E_{s,2024}}{E_{s,1970}} - 1 \right) * 100$	It shows by what percentage the 2024 value increased/decreased compared to 1970.
CAGR	$CAGR_s = \left[\left(\frac{E_{s,2024}}{E_{s,1970}} \right)^{1/54} - 1 \right] * 100$	The compound annual growth rate (CAGR) was used to measure long-term change. The overall growth trend between the initial and final years was evaluated through an average annual rate. Since the 1970–2024 period covers 54 years, the exponent value was taken as 1/54 (Gomonov et al., 2025;Congedo et al., 2025).

AAGR	$AAGR_s = \frac{1}{54}\sum_{t=1971}^{2024}\left[\left(\frac{E_{s,t} - E_{s,t-1}}{E_{s,t-1}}\right) * 100\right]$	The arithmetic annual average growth rate (AAGR) was calculated to monitor annual fluctuations and the dynamics of change within the period.
Sectoral share	$Pay_{s,t} = \frac{E_{s,t}}{E_{Toplam,t}} * 100$	It shows the weight of each sector within the total for the relevant year.
Contribution to the total increase	$Katkı_s = \frac{\Delta E_s}{\Delta E_{Toplam}} * 100$	It shows how much of the total increase during the 1970–2024 period originated from the relevant sector.

Source: Prepared by the author. NOTE 1: The unit of the raw dataset used in the study is expressed in Mt CO_2/year. Therefore, the sectoral and total emission values used in the analysis indicate the annual fossil CO_2 emission level, which is realized for the relevant year. Since percentage change, AAGR, CAGR, sectoral share, and contribution to the total increase are proportional indicators, they are reported in percentage (%) terms. NOTE 2: All formulas used in the analysis were calculated separately for each period.

3.2. Analysis Results

The sector-based diffirent carbon emission results for Turkey for the 1970–2024 period[1] show that the increase in total emissions was not distributed equally across all sectors, but was concentrated around the energy industry, transportation,

[1] This contains the analysis results, which is provided in the Appendices section.

industrial fuel combustion, buildings, and industrial processes. The strongest driver of the increase in total emissions is the electricity/energy production sector. While the emission level was 8.28 Mt CO_2/year in 1970, it increased to 140.91 Mt CO_2/year in 2024. In 2024, the emission level was 132.63 Mt CO_2/year higher than in 1970. The total rate of change was 1602.22%, indicating that the emission level increased by approximately 17 times compared to 1970. The CAGR was 5.39%, which reveals that the sector's long-term average annual compound growth rate was quite high. The sector's share in total emissions increased from 18.21% in 1970 to 30.63% in 2024. This increase shows that the sector grew not only in terms of absolute emission volume but also in terms of its weight within total emissions. With a contribution of 31.99% to the increase in total emissions, the sector recorded the highest level among all sectors. This increase demonstrates that carbon emissions in Turkey have exhibited a strong, continuous, and structural growth trend over the long term (Isik et al., 2021). It also shows that the use of fossil fuels in electricity and energy generation has played a central role in Turkey's long-term increase in carbon emissions. In this context, regarding carbon reduction in the Energy Industry sector, the fossil fuel-dominated production structure should be gradually replaced with low-carbon sources, and investments in solar, wind, geothermal, biomass, and hydroelectric energy should be increased. Efficiency improvements should be implemented in electricity generation facilities (Hou et al., 2025), transmission and distribution losses should be reduced, and technology renewal processes in thermal power plants should be accelerated. Renewable energy, energy storage, grid modernization, clean technology, and efficiency investments create a substantial need for financing. Therefore, green bonds, sustainability-linked loans, climate finance funds, publicly supported guarantee mechanisms, and carbon market revenues should be used effectively to finance the energy transition.

The transportation sector is the second major source of the increase in total emissions. While the emission level was 10.28 Mt CO_2/year in 1970, it increased to 99.29 Mt CO_2/year in 2024. The sector's emission level increased by 89.01 Mt CO_2/year. The total rate of change was 866.13%, indicating that transportation-related emissions increased by approximately 9.7 times compared to 1970. The sector's CAGR was 4.29%. This shows that the long-term increase in emissions in the transportation sector has followed a strong and continuous trend. The share of the transportation sector in total emissions was 22.61% in 1970 and 21.58% in 2024. The sector's contribution to the increase in total emissions was quite high, at 21.47%. In particular, the fact that the transportation sector's contribution to the total increase reached 55.31% during the 2020–2024 period reveals that transportation has become the strongest determinant of emission growth in the

most recent period. This situation can be associated with a road-dominated transportation structure, private vehicle use, logistics mobility, urbanization, and the expansion in the volume of economic activity. Regarding carbon reduction in the transportation sector, the road-dominated transport structure should be gradually reduced, and the share of rail and maritime transport should be increased (Saboori et al., 2014; Güzel & Alp, 2020). In particular, dependence on road transport in freight transportation should be reduced, and railway connections among ports, organized industrial zones, logistics centers, and production areas should be strengthened. Energy efficiency policies in the transportation sector should be strengthened. Reducing fuel consumption per vehicle, low-emission vehicle standards, decreasing empty trips in logistics, and prioritizing efficient modes in freight transport are key instruments in this context. Electric and low-emission vehicle technologies should be expanded (Li et al., 2023). Electric and hybrid vehicles (Güzel & Alp, 2020), hydrogen-based heavy-duty vehicle technologies, sustainable aviation fuels, electric public transportation fleets, and charging infrastructure supported by renewable energy should be considered important instruments for the decarbonization of the transportation sector.

The industrial fuel combustion sector contributed 16.41% to the increase in total emissions during the 1970–2024 period. Sectoral emissions increased from 6.99 Mt CO_2/year to 75.02 Mt CO_2/year, rising by approximately 10.7 times. The limited increase in the sector's share from 15.38% to 16.31% indicates that industry-related energy consumption maintained its weight in Turkey's total emissions structure. From a periodic perspective, during the 1970–1979 period, industrial fuel combustion was one of the main drivers of the total increase, with a contribution rate of 36.01%. By contrast, in the 2000–2009 period, sectoral emissions declined from 58.03 Mt CO_2/year to 41.62 Mt CO_2/year, and its contribution to the total increase was calculated as-22.08%. This shows that emissions from industrial fuel combustion had a reducing effect on the total increase during this period. However, a strong increase occurred again during the 2010–2019 period, and the sector contributed 17.99% to the total increase. This result indicates that changes in industrial production, energy demand, and fossil fuel use are decisive for sectoral emissions. Regarding carbon reduction in the industrial fuel combustion sector, energy efficiency in industrial facilities should be made a mandatory and monitorable area of transformation. Fossil fuel use in industry should be gradually reduced, and the transition to low-carbon energy sources should be accelerated. The use of high-carbon fuels should be reduced; sectoral roadmaps should be developed for the transition from natural gas to low-carbon gases, biofuels, renewable electricity, and green hydrogen. Electrification and renewable energy integration in industry should be strengthened. Electric

boilers, industrial heat pumps, electric furnaces, and renewable energy-supported production systems are important instruments that can reduce emissions from industrial fuel combustion. In organized industrial zones and large industrial facilities, rooftop solar power plants, ground-mounted solar power plants, wind energy, biomass, and waste heat-supported energy generation should be expanded; these investments should be planned together with storage and smart grid infrastructure. Separate carbon reduction programs should be prepared for energy-intensive subsectors such as iron and steel, cement, chemicals, fertilizers, glass, ceramics, and the metal industry (Bahçekapılı, 2025).

The buildings sector contributed 14.92% to the total increase over the long term and increased its emission level from 10.85 Mt CO_2/year to 72.69 Mt CO_2/year. Although sectoral emissions increased by approximately 6.7 times, its share in the total declined from 23.87% to 15.80%. This indicates that building-related emissions increased in absolute terms; however, the relative weight of buildings decreased because emissions in sectors such as the energy industry, transportation, and industry increased more rapidly. The most notable period for the buildings sector was 2000–2009. During this period, the emission level increased from 33.50 Mt CO_2/year to 63.18 Mt CO_2/year, and its contribution to the total increase was 39.94%. This finding reveals the impact of the expansion in building stock, residential and commercial building areas, urbanization, heating and cooling demand, and energy consumption on emissions during the 2000s. In the post-2010 period, the growth rate in the buildings sector slowed significantly. Regarding carbon reduction in the buildings sector, the existing building stock should be renovated with a focus on energy efficiency. A comprehensive renovation program should be implemented for existing residential, commercial, and public buildings, including insulation, high-efficiency heating and cooling systems, efficient lighting, energy management systems, and improvements to the building envelope. Low-carbon building standards should be made mandatory for new buildings. The use of renewable energy in buildings should be expanded. The low-carbon transformation of heating and cooling systems should be accelerated.

The industrial processes sector contributed 11.82% to the increase in total emissions during the 1970–2024 period. Sectoral emissions increased from 5.39 Mt CO_2/year to 54.37 Mt CO_2/year, rising by approximately 10.1 times. Despite this, the sector's share in the total remained almost unchanged, from 11.85% to 11.82%. This result indicates that industrial processes have had a stable and structural weight in Turkey's emissions composition over the long term. In particular, the increase in the sector's contribution to the total rise to 18.82% during the 2000–2009 period shows that activities generating process-related emissions, such as cement, metal, chemical, and basic materials production,

became more prominent during this period. Therefore, industrial processes should be evaluated not only through energy efficiency policies, but also together with production technology, raw material use, process transformation, and low-carbon production standards. Regarding carbon reduction in the industrial processes sector, process-related emissions should be analyzed separately for each subsector in terms of emission intensity per unit of product, raw material structure, process technology, energy source, and mitigation potential. Low-carbon production technologies should be expanded. Another key policy area is the strengthening of material efficiency and circular economy practices. Sector-based carbon intensity standards and green product criteria should be established. Common transformation infrastructures should be developed through industrial clusters and organized industrial zones.

The fuel extraction sector increased its emission level from 2.95 Mt CO_2/year in 1970 to 15.62 Mt CO_2/year in 2024 and contributed 3.06% to the total increase. Although the emission level increased by approximately 5.3 times, the sector's share declined from 6.48% to 3.40%. This indicates that the sector grew in absolute terms; however, its relative importance decreased because total emissions increased more rapidly in sectors such as the energy industry, transportation, and industry. The decline in fuel extraction emissions during the 2020–2024 period and its contribution to the total increase being -2.01% indicate that the sector had a limiting effect on the increase in total emissions in the most recent period. Nevertheless, the sector remains a complementary area that should be monitored in terms of the fossil fuel supply chain, fugitive emissions, production processes, and energy supply security. Regarding carbon reduction in the fuel extraction sector, energy efficiency should be increased in fuel extraction and operation processes. The energy consumption of equipment used in the sector, the electricity needs of production sites, and the efficiency levels of pumps, compressors, boilers, motors, and transportation systems directly affect emissions. Therefore, energy audits should be conducted in production facilities, the use of high-efficiency equipment should be supported, systems based on outdated technologies should be gradually renewed, and facility-level energy management systems should be implemented. Fugitive emissions and process losses should be monitored regularly. For this reason, measurement, reporting, and verification infrastructure should be strengthened in facilities; emissions should be monitored by facility, sub-activity, and fuel type. Regular data collection and transparent reporting will contribute to setting realistic reduction targets for the sector. Technical standards should be developed to reduce emissions arising from flaring, venting, and inefficient fuel use. It is important that gases released during production and operation processes be recovered,

reused, or directed to lower-emission systems to the extent that this is economically and technically feasible. Gas recovery systems, closed-system technologies, digital monitoring sensors, and low-emission equipment applications should be considered priority investment areas in this field.

The agriculture and waste sectors have a limited effect on the total increase in terms of carbon emissions. While emissions from the agriculture sector were 0.72 Mt CO_2/year in 1970, they increased to 2.12 Mt CO_2/year in 2024; its contribution to the total increase was only 0.34%. The sector's share in the total declined from 1.58% to 0.46%. This finding indicates that the agriculture sector is not among the main emission sources in terms of carbon emission. However, the agriculture sector is important within the broader scope of greenhouse gas management due to issues such as methane, nitrous oxide, fertilizer use, livestock, irrigation, and land management. The waste sector, on the other hand, had a very low emission volume during the 1970–2024 period and did not make a meaningful contribution to the total increase in terms of carbon emission. Nevertheless, the waste sector is a strategic complementary policy area in terms of landfilling, organic waste management, wastewater treatment, methane reduction, biogas, and circular economy policies. Regarding carbon reduction in the agriculture sector, energy efficiency in agricultural energy use should be increased, and the use of renewable energy should be expanded (Coşgun, 2021). Agricultural irrigation systems, greenhouse production, tractors and agricultural machinery, cold storage facilities, product processing plants, and agricultural logistics activities generate emissions through energy consumption. Therefore, the use of energy-efficient pumps in pressurized irrigation systems, the expansion of drip and sprinkler irrigation systems, the implementation of energy audits in agricultural enterprises, and the renewal of machinery and equipment based on outdated technologies should be supported. In particular, the fact that agriculture-related emissions increased by approximately three times during the 1970–2024 period shows the importance of energy efficiency-oriented interventions in the sector, even though the emission volume remains low. Fertilizer management and precision agriculture practices should be strengthened. Therefore, soil analysis-based fertilization, variable-rate fertilizer applications, the use of organic fertilizer, cover crop practices should be expanded in agricultural soils (Poeplau & Don, 2015), Training should be provided to increase farmers' awareness (Everest, 2021) and compost, increasing nitrogen use efficiency, and digital agriculture technologies should be supported.

4.Policy Recommendation within the Framework of Green and Climate Macroeconomics

The carbon emission trends of different sectors in Turkey provide an important analytical basis for the preparation and implementation of climate macroeconomic policies. The sector-based carbon emission analysis results for Turkey for the 1970–2024 period show that emission growth was concentrated in specific sectors. This finding indicates that carbon intensity should not be addressed solely from an environmental perspective, for it also reflects the need for macroeconomic transformation across all sectors.

The sector-based carbon emission results for the 1970–2024 period show that the increase in total emissions was mainly concentrated in the energy industry, transportation, industrial fuel combustion, buildings, and industrial processes sectors. The energy industry increased its emission level from 8.28 Mt CO_2/year in 1970 to 140.91 Mt CO_2/year in 2024, making it the sector with the highest contribution to the increase in total emissions and the main determinant of Turkey's long-term emission growth (Isik et al., 2021).

The transportation sector increased from 10.28 Mt CO_2/year to 99.29 Mt CO_2/year during the 1970–2024 period; particularly in the 2020–2024 period, it contributed 55.31% to the total increase, making it one of the sectors in which emission growth has occurred most prominently in the recent period. The industrial fuel combustion and industrial processes sectors contributed to the long-term increase in emissions in connection with the production structure, industry-related energy consumption, and basic materials production. The buildings sector also showed a significant increase in terms of absolute emission levels; however, its relative share in the total declined due to the faster increase in the energy and transportation sectors. By contrast, the contributions of the agriculture, fuel extraction, and waste sectors to the increase in total emissions remained more limited.

Overall, the increase in carbon emissions in Turkey has not been distributed equally across all sectors; rather, it has been concentrated around energy generation, transportation, industry, and buildings. Therefore, climate policies should be designed according to priority sectors, taking into account sectors' contributions to the total increase and their periodic emission trends. In this context, climate policies need to be supported by energy transformation, low-carbon transportation, clean production in industry, energy efficiency in the building stock, and circular economy practices. Considering the findings obtained and the studies in the literature, it is revealed that low-carbon development

policies in Turkey should be prepared according to priority sectors (Bahçekapılı, 2025).

Climate policy in Turkey should not be designed solely as a policy for reducing carbon intensity; rather, it should be prepared as a climate macroeconomic policy that needs to be addressed together with growth, production costs, energy supply security, the foreign trade balance, public finance, financial stability, and green investment capacity (Hou et al., 2025;Ali & Mujahid, 2024). The success of countries' carbon reduction efforts depends on increasing labor productivity and R&D efficiency (Hou et al., 2025), improving the quality of human capital (Kazar, 2024), institutional conditions, setting carbon targets on a scientific and institutional basis, preparing and implementing climate action plans by taking macroeconomic dynamics into account, and supporting them through fiscal policies (Tsvetkov & Andreichyk, 2025).

Climate change and climate policies affect the macroeconomy through the real sector, fiscal policy, foreign trade, monetary policy, and the financial sector. It leads to an increase in carbon emissions from economic activities (Abbes, 2021). Therefore, incorporating climate risks into macroeconomic analyses and scenario studies will have an impact on countries' economic growth (Saboori et al., 2014). The recommended basic approach for Turkey is to align sector-specific emission reduction targets with macroeconomic policies. In this context, the energy industry should be placed at the center of climate macroeconomics policy. This is because both the results of analyses and relevant studies indicate that the energy industry is one of the primary sources of the increase in carbon emissions (Isik et al., 2021;Inam et al., 2025). Consequently, energy efficiency policies aimed at reducing the carbon intensity of electricity generation should be made a macroeconomic priority. In other words, implementing measures to reduce carbon emissions in the energy sector could also have positive effects on the current account balance, exchange rate pressures, and production costs by reducing dependence on energy imports. For this reason, the energy transition should be viewed as a strategic area at the intersection of climate policy, energy security, and foreign trade policies (Millard, 2023).

The increase in the contribution to the total increase in the transportation sector to 55.31% in the 2020–2024 period shows that this sector has become one of the strongest sources of emission growth in the current period (Abbes, 2021). Therefore, carrying out studies aimed at reducing carbon emission intensity in the transportation sector will be one of the areas with high environmental and macroeconomic effects. In this context, fuel types should be changed for the transportation sector (Abbes, 2021), electric and hybrid vehicles (Güzel & Alp,

2020; Li et al., 2023) and low-carbon production and transportation transformation should be accelerated for industrial sectors. Low-carbon transformation in the transportation sector may create positive effects on the current account balance by reducing the pressure of fuel imports, which is one of the main production inputs of all sectors. In addition, it may provide indirect benefits in terms of health expenditures and labor productivity through the increase in urban air quality.

Industrial fuel combustion and industrial processes are sectors that directly affect firms' production structure, national/international competitiveness, and foreign trade from the perspective of climate macroeconomics. Reducing emissions in energy- and carbon-intensive sectors, including cement, iron and steel, chemicals, glass, ceramics, and basic metals, affects not only environmental performance but also access to international markets and the capacity to comply with carbon border regulations.

The buildings sector is a sector with a strong social dimension from the perspective of climate macroeconomics because it is directly related to energy demand, urbanization, household expenditures, and energy poverty. Implementing policies aimed at increasing the energy efficiency of the existing building stock will contribute to reducing carbon intensity and lowering household energy expenditures (Atmaca & Atmaca, 2022;Yardımcı et al., 2024). In this context, the buildings sector should be addressed together with the social justice dimension of green transformation; access of low-income households to energy efficiency investments should be strengthened through public support, low-interest loans, and targeted incentives.

Although the share of the agriculture, waste, and fuel extraction sectors in carbon emissions appears limited in some countries, these sectors should not be neglected from the perspective of climate macroeconomics. The agriculture sector has strategic importance in terms of food prices, water resources, rural income, fertilizer use, methane emissions from livestock, and climate adaptation capacity. The waste sector, on the other hand, generates both environmental and economic benefits through methane reduction, recycling, biogas, organic waste management, and circular economy practices. In the fuel extraction sector, methane leaks, energy efficiency, electrification of production sites, and supply chain carbon intensity are important in terms of reducing the climate impacts of fossil fuel supply (Alvarez et al., 2018; Lauvaux et al., 2022). Policies to be implemented in these sectors will contribute not only to carbon reduction but also to resource efficiency, rural development, energy supply security, and local economic resilience.

From the perspective of climate macroeconomics, carbon pricing, an emissions trading system, green budgeting, sustainable public investments, and green financing mechanisms should be addressed in an integrated manner. Carbon pricing can encourage the transition to low-carbon technologies by making the carbon cost visible in production and consumption decisions. However, implementing such policy instruments without taking into account their effects on economic growth, employment, income distribution, and sectoral competitiveness may increase costs during the transition process. Therefore, it is important to direct carbon revenues to energy efficiency investments, supporting low-income households, technological transformation in industry, and green infrastructure investments. Thus, climate policies may go beyond being environmental instruments that only provide emission reduction and become fiscal policy instruments that guide economic transformation (Millard, 2023).

5. Conclusion

This study examined the long-term development and dynamics of carbon emissions across different sectors in Turkey during the 1970–2024 period. The analysis results show that the increase in total emissions in Turkey is concentrated in a limited number of sectors. This finding is consistent with studies that take different sectors into account. The energy industry, transportation, industrial fuel combustion, buildings, and industrial processes sectors stand out as the main determinants of the increase in total emissions. By contrast, the shares of the agriculture, fuel extraction, and waste sectors in the total increase in emissions remained more limited.

The findings of the study indicate that climate policies in Turkey should be designed with a sector-based approach that also takes macroeconomic effects into account. Identifying the sectors that make the highest contribution to emission growth enables the establishment of policy priorities. In this context, the energy industry, transportation, industrial fuel combustion, buildings, and industrial processes should be considered priority areas for intervention, while the agriculture, waste, and fuel extraction sectors should be supported through complementary mitigation and adaptation policies.

As a result, in order for Turkey to strengthen its low-carbon development process in line with its 2030 and 2053 climate targets, emission reduction policies should not be limited solely to environmental objectives. These policies should be addressed together with dimensions such as energy security, the current account balance, production costs, industrial competitiveness, green finance, employment,

technological capacity, and social justice. Within this framework, sector-based emission analysis provides an important analytical basis for developing Turkey's green transformation strategies in a scientific, measurable, and policy-oriented manner.

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Table 1: Turkey's Total Emissions Results by Sector Between 1970-2024

Period	Sector	Start Value	End Value	Absolute Change	Total Change %	CAGR %	AAGR %	Start Share %	End Share %	Contribution to Total Change %
1970	**Agriculture**	0.72	1.29	0.57	79.69	6.73	9.35	1.58	1.65	1.73
1979	Buildings	10.85	14.31	3.46	31.87	3.12	3.68	23.87	18.24	10.48
	Fuel Extraction	2.95	4.31	1.36	46.15	4.31	6.78	6.48	5.49	4.12
	Industrial Combustion	6.99	18.87	11.88	169.90	11.66	12.26	15.38	24.06	36.01
	Energy Industry	8.28	13.37	5.09	61.45	5.47	5.61	18.21	17.04	15.42
	Processes	5.39	8.82	3.43	63.77	5.63	5.94	11.85	11.24	10.41
	Transportation	10.28	17.47	7.19	69.97	6.07	6.37	22.61	22.27	21.80
	Waste	0.01	0.01	0.01	65.76	5.78	5.78	0.02	0.02	0.02
1980	**Agriculture**	1.19	1.20	0.02	1.31	0.14	0.73	1.45	0.87	0.03
1989	Buildings	17.43	27.49	10.06	57.70	5.19	5.62	21.31	19.89	17.83
	Fuel Extraction	4.32	8.27	3.95	91.52	7.49	7.70	5.27	5.98	7.00
	Industrial Combustion	20.78	29.79	9.02	43.41	4.09	4.35	25.39	21.55	15.99
	Energy Industry	12.91	31.14	18.23	141.30	10.28	12.22	15.77	22.53	32.33
	Processes	8.45	14.36	5.91	69.92	6.07	6.39	10.33	10.39	10.48

	Transportation	16.74	25.95	9.21	54.98	4.99	5.09	20.46	18.77	16.32
	Waste	0.02	0.03	0.01	83.80	7.00	7.00	0.02	0.02	0.02
1990	**Agriculture**	1.29	2.02	0.73	56.55	5.11	6.36	0.83	0.99	1.48
1999	Buildings	28.71	31.50	2.79	9.73	1.04	1.39	18.50	15.40	5.66
	Fuel Extraction	8.84	9.70	0.87	9.81	1.05	1.73	5.70	4.74	1.76
	Industrial Combustion	32.76	41.36	8.60	26.25	2.62	3.15	21.11	20.22	17.41
	Energy Industry	33.82	65.31	31.49	93.09	7.58	7.68	21.80	31.93	63.73
	Processes	21.87	21.35	-0.52	-2.38	-0.27	-0.01	14.09	10.44	-1.05
	Transportation	27.85	33.30	5.45	19.56	2.00	2.35	17.95	16.28	11.03
	Waste	0.03	0.03	0.00	9.63	1.03	3.10	0.02	0.02	0.01
2000	**Agriculture**	1.67	2.50	0.83	49.60	4.58	5.57	0.73	0.83	1.11
2009	Buildings	33.50	63.18	29.68	88.62	7.31	7.87	14.75	20.96	39.94
	Fuel Extraction	9.33	13.00	3.67	39.36	3.76	4.34	4.11	4.31	4.94
	Industrial Combustion	58.03	41.62	-16.41	-28.28	-3.63	-1.36	25.56	13.81	-22.08
	Energy Industry	68.36	101.41	33.05	48.35	4.48	4.78	30.11	33.65	44.48
	Processes	21.41	35.40	13.98	65.31	5.74	5.81	9.43	11.74	18.82
	Transportation	34.74	44.26	9.52	27.42	2.73	2.93	15.30	14.69	12.81

	Waste	0.03	0.02	-0.01	-34.38	-4.57	3.07	0.01	0.01	-0.02
2010	**Agriculture**	2.33	2.35	0.02	0.71	0.08	1.26	0.75	0.57	0.02
2019	Buildings	63.00	66.51	3.51	5.57	0.60	0.92	20.18	16.05	3.43
	Fuel Extraction	12.89	18.79	5.89	45.70	4.27	4.93	4.13	4.53	5.76
	Industrial Combustion	48.68	67.08	18.40	37.80	3.63	4.34	15.59	16.19	17.99
	Energy Industry	102.02	133.75	31.73	31.10	3.05	3.36	32.68	32.27	31.01
	Processes	39.84	42.48	2.64	6.62	0.71	0.89	12.76	10.25	2.58
	Transportation	43.39	83.52	40.13	92.51	7.55	7.74	13.90	20.15	39.23
	Waste	0.01	0.00	-0.01	-92.35	-24.84	-2.16	0.00	0.00	-0.01
2020	**Agriculture**	2.99	2.12	-0.86	-28.96	-8.19	-7.70	0.71	0.46	-2.34
2024	Buildings	71.46	72.69	1.22	1.71	0.43	0.48	16.89	15.80	3.31
	Fuel Extraction	16.37	15.62	-0.74	-4.55	-1.16	-0.90	3.87	3.40	-2.01
	Industrial Combustion	73.28	75.02	1.74	2.37	0.59	0.91	17.32	16.31	4.71
	Energy Industry	128.82	140.91	12.09	9.39	2.27	2.41	30.45	30.63	32.73
	Processes	51.31	54.37	3.06	5.96	1.46	1.66	12.13	11.82	8.28
	Transportation	78.86	99.29	20.43	25.91	5.93	6.05	18.64	21.58	55.31
	Waste	0.00	0.00	0.00	118.60	21.59	21.77	0.00	0.00	0.01

1970	**Agriculture**	0.72	2.12	1.40	195.34	2.03	3.35	1.58	0.46	0.34
2024	Buildings	10.85	72.69	61.84	569.80	3.58	4.02	23.87	15.80	14.92
	Fuel Extraction	2.95	15.62	12.68	430.14	3.14	3.99	6.48	3.40	3.06
	Industrial Combustion	6.99	75.02	68.03	972.95	4.49	5.46	15.38	16.31	16.41
	Energy Industry	8.28	140.91	132.63	1602.22	5.39	5.91	18.21	30.63	31.99
	Processes	5.39	54.37	48.98	909.45	4.37	4.81	11.85	11.82	11.82
	Transportation	10.28	99.29	89.01	866.13	4.29	4.53	22.61	21.58	21.47
	Waste	0.01	0.00	0.00	-56.20	-1.52	5.09	0.02	0.00	0.00

Source: Prepared by the author.

The Sustainability Of Turkish External Debt Revisited: Nonlinear Unit Root Evidence With The New Data Set And Methodology

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Abstract

The size of Türkiye's external debt, particularly in the 2000s, is worrying, and its growing burden is noteworthy. This paper investigates Türkiye's external debt sustainability using a nonlinear Exponential Smooth Transition Autoregressive (ESTAR) unit root test by Hepsağ (2021). First, a sustainability criterion is established. According to this criterion, unit root tests are employed on the discounted net real external debt stock. Several aspects distinguish this research from other studies in the field. Firstly, unlike most unit root tests in the field, the test in this article is based on a theoretical sustainability condition. Secondly, nonlinear unit root tests, which are more robust and account for breaks, are applied. Finally, the external debt stock series (2005:Q4-2025:Q2), calculated using new methods and data released by the Central Bank of the Republic of Türkiye (CBRT) on March 12, 2026, is used. The findings indicate that Türkiye's external debt is unsustainable.

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I. Introduction

There can be various reasons behind the non-repayment of external debt. Each of these different reasons points to different external debt problems. Each problem has different meanings and consequences for both lenders and borrowers. Basically, there are three main reasons why a country might default on its external debt: liquidity insufficiency, unwillingness to repay, and inability to repay (Sachs, 1984; Utkulu, 1995; Önel and Utkulu, 2006). Theoretical models and approaches corresponding to these different reasons have been developed in the relevant literature (Atasert and Utkulu, 2025). First, it should be noted that in the case of liquidity insufficiency, the external debt crisis is short-term and temporary. In this case, although the country has the resources to pay its debt back over the long term, it cannot meet its short-term debt repayment obligations with its current resources. In the event of an inability to repay, the country cannot pay its debt back in the long term. Here, the country is ready to repay its debt liabilities if it can afford to do so. The debtor country has the resources to meet its debt obligations in the long term without playing a Ponzi scheme (i.e., using newly acquired debt to service existing debt). Finally, even if the debtor country has no short-term liquidity problems and has the resources to repay its debt obligations in the long term, it may still choose not to repay. This approach assumes that the country decides based on a comparison of the benefits and costs of repaying its external debt. If the costs outweigh the benefits, the country may decide not to repay the debt. However, in international financial markets, the high cost of non-repayment (risk of asset seizure; decreased credibility; potential reactions in international politics; risk of inability to borrow again in the future; risk of decreased export revenues, etc.) often pushes the country to repay its debt (Krugman and Obstfeld, 1991).

This study focuses on the solvency, i.e., sustainability of Türkiye's external debt. External debt sustainability is a long-term concept related to the ability to repay debt. A country with a sustainable external debt stock possesses the resources to meet its debt obligations in the long term without playing a Ponzi scheme. Conversely, a country with unsustainable external debt cannot fulfill its outstanding debt liabilities in the long term without playing a Ponzi scheme. No country can play a Ponzi scheme forever. In other words, every Ponzi scheme has a limit and an end. In a country with unsustainable external debt, the external debt management strategy fails and must be changed. Both the country's growth and current account policies must be urgently reviewed. However, only with successful growth and current account policies can the country's risk premium be reduced and its credibility and reputation increased. Unsustainable external debt indicates a debt overhang, or excessive debt burden. In this situation, investment

decreases and comes to a standstill, new borrowing costs become very high, and, from this point on, any rise in the external debt stock declines economic growth. This is why the sustainability of a country's external debt is of vital importance (Atasert and Utkulu, 2025).

Both cointegration and unit root methodologies have proven effective instruments for examining the long-run effects of a nation's or government's intertemporal sustainability. First, cointegration is required for the country to satisfy its intertemporal budget constraint. The cointegration test examines whether a government or country can continue its fiscal or external deficits without increasing its debt. Early literature on a government's solvency includes contributions such as Hamilton and Flavin (1986), Wilcox (1989), Trehan and Walsh (1988, 1991), Hakkio and Rush (1991a), Corsetti and Roubini (1991), Buiter and Patel (1992), Tanner and Liu (1994), Liu and Tanner (1995), Tanner (1995). Özatay (1994) also applies the same methodology to test the sustainability of Türkiye's fiscal deficits. Most early studies examine the sustainability of government deficits within an autarchy setting.

Instead, Trehan and Walsh (1991) develop a methodology within an open-economy framework. According to this procedure, a requirement for the solvency of the external debt is the stationarity of the discounted net real external debt stock. As an alternative, Hakkio and Rush (1991a) offer a procedure for testing the long-term equilibrium (i.e., cointegrating) properties of the exports and imports. To this procedure, the existence of cointegration between imports and exports is an essential requirement for the country to sustain deficits (i.e., intertemporal sustainability). Both approaches, beginning with the balance-of-payments identity and accounting for intertemporal budgetary dynamics, yield testable empirical models. Then, Sawada (1994) not only provides a compact, relevant theoretical basis but also applies it to the solvency of heavily indebted developing countries. Early contributions, such as Bean (1991), Dolado and Vinals (1991), Trehan and Walsh (1991), Husted (1992), Wickens and Uçtum (1993), and Bahmani-Oskooee (1994), investigate external solvency only in developed countries.

Regarding Türkiye’s external debt, only a limited number of pioneering studies use these procedures to assess its sustainability. Bahmani-Oskooee and Domac (1995) provide proof of cointegration between imports and exports only when a dummy for a structural break in 1973 is included in the long-run equations. Utkulu (1998), following the methodology of Hakkio and Rush (1991a), finds no evidence of cointegration between Turkish exports and imports using annual data, indicating that the country's intertemporal budget constraint is violated.

Utkulu (1999) also confirms similar findings, i.e., the nonstationary structure of Turkish external debt, using the unit root testing framework of Trehan and Walsh (1991).

It is also important to note that the effects of real and monetary shocks are permanent in the case of unit root existence, that is, the shocks are temporary if the series is stationary (Taylor, 1989). A stationary time series converges with its unconditional mean (i.e., expected value) in the long run. In this case, real or monetary shocks reduce and disappear over time. By analogy, if the external debt variable is stationary, this also implies that the effects of real and monetary shocks on the debt variable are temporary, i.e., they fade away and disappear over time.

By the 2000s, and especially after 2010, Turkey's rapidly increasing external debt burden has raised serious concerns about its sustainability, both in academia and in the national/international political arena. Therefore, the number of studies investigating the sustainability of Türkiye's external debt has also increased in the 2000s. Among these studies are those by Azgün (2005), Önel and Utkulu (2006), Yılancı and Özcan (2008), Kıran (2012), Çukurçayır (2014), Göktaş and Hepsağ (2015), Sellavtzi (2017), Dağ and Kızılkaya (2018), Uslu (2019), Yalçınkaya (2019), Yenisu (2020), Dayıoğlu et al. (2020), Konat (2021), Yurdadoğ et al. Examples of studies on this topic include Özbek and Türkmen (2021), Akın and Güneş (2022), Dallı (2022), Gümüş (2022, 2026), Kaya et al. (2025), Atasert and Utkulu (2025), and Yakşi and Kayantaş (2026). Examining the relevant literature and findings reveals several observations. Firstly, the findings regarding the sustainability of Türkiye’s external debt do not show consensus but rather divergence. This divergence may be due to various factors: differences in theoretical models and empirical methods, differences in the data and periods covered by the research, etc. Another point is that some studies apply different unit root tests to external debt ratios without deriving or considering a sustainability condition based on the balance-of-payments identity and the intertemporal budget constraint. This can be considered an example of applications not based on theory. Finally, as of March 12, 2026, the methodology for calculating external debt statistics has been changed to align with the International Monetary Fund's external debt statistics criteria. External debt statistics, previously announced by the Ministry of Treasury and Finance, are now published by the Central Bank of the Republic of Türkiye (CBRT) using the new methodology and data. This methodological change naturally affects external debt statistics. For example, when comparing the gross external debt stock series compiled using the old method with the series calculated using the new method, this methodological alignment increased the external debt stock

during the 2005-2016 period but decreased it after 2017. Thus, in the third quarter of 2025, the gross external debt stock, which was previously $565 billion, fell to $500 billion when calculated using the new method. According to the new calculation method, the holder's domicile is used instead of the issuance location. Furthermore, with the new method, market values are used instead of nominal amounts for valuation, resulting in updated (discounted) values. As a result of the new calculation, external debt statistics have been updated retrospectively to 2005 (CBRT, 2026).

Thus, the contribution of this paper is threefold. Firstly, it conducts empirical tests based on the intertemporal budget constraint sustainability condition, which is grounded in a balance-of-payments identity. Secondly, it uses nonlinear unit root tests, which yield stronger results than linear methods in the relevant field (see Kapetanios, Shin, and Snell (2003). Finally, it uses the newly published, retrospectively updated external debt statistics from the CBRT.

This paper examines the sustainability, i.e., the solvency, of Türkiye's external debt using the method introduced by Trehan and Walsh (1991) and later theoretically grounded by Sawada (1994). The method implies that stationarity of the discounted net real external debt is an essential condition for the solvency of external debt. The empirical model of sustainability, i.e., the solvency of external debt in this paper, emerges from the balance-of-payments identity.

The following section provides the sustainability condition. Section three includes the data and methodology, while section four focuses on the application and findings. The final section recommends some policy implications.

II. The Sustainability Condition

The following sustainability (i.e., solvency) condition is derived from the balance-of-payments identity and is subject to intertemporal budget restrictions. That is, the sustainability condition is met:[3]

$$D_t = E_t \sum_{j=t+1}^{\infty} \frac{S_j}{\prod_{i=1}^{j-t}(1 + r_{t+j})} \tag{1}$$

[3] For the theoretical derivation process of intertemporal sustainability, see Utkulu (1995), Sawada (1994), Trehan and Walsh (1991), Cohen (1991), Buiter (1990a, 1990b), Currie and Levine (1991).

where D, S, and r state the net real external debt stock, primary surpluses, and real interest rates, respectively. E_t denotes the expectations constructed at time t. Equation (1) implies that the net real external debt due at time t is required to be equivalent to the present value of the future net surplus if the country is sustainable. Equation (1) corresponds to the following requirement:

$$E_t \lim_{N\to\infty} \frac{D_N}{\prod_{j=1}^{N-t}(1+r_{t+j})} = 0 \qquad (2)$$

This is the alleged no-Ponzi-game requirement in the field.[4] It expresses that the present value of future net real external debt converges to zero in the long term, provided the country is sustainable. This means that the country cannot play an effective "Ponzi game". If the left-hand side of (2) is positive and the outstanding external debt exceeds expected future payments, then the country's external debt is unsustainable and thus suffers from a debt overhang.

Equation (2) exhibits the forecast function for the discounted net real external debt stock (see Özatay, 1994). When the debt stock converges to zero in the limit, this implies that the forecast for the debt stock at time t over a very long period is zero. For equation (2) to hold, the discounted net real external debt stock is to be stationary, and the mean of the debt should be zero. If this condition is met, the intertemporal budget restriction is not violated, and the sustainability of external deficits and debt is achieved.

III. Data Set and Methodology

Considering the sustainability condition derived in the previous section, this study empirically examines whether Türkiye's external debt is sustainable. The calculations utilize quarterly net external debt stock data in US dollars (2005:Q4-2025:Q2) published by the Central Bank of the Republic of Türkiye on March 12, 2026. As is known, net external debt stock is calculated as the difference between external debt liabilities and external assets. Net external debt stock is evaluated as the net of liabilities and assets, excluding non-debt-creating elements in the international investment position (direct investments plus portfolio equity investments). A positive sign indicates net debt stock (CBRT, 2026).

The newly published net external debt stock figures reflect market values rather than nominal values and therefore represent discounted net external debt stock

[4] The existence of dynamic inefficiency in the long term is ruled out.

figures. Finally, to make this dataset compliant with the sustainability condition, the US GDP deflator was used to realize the net real external debt stock (DNRED) dataset.

It is considered an unexpected situation in economic series when the proportional changes in a variable over time are the same. Therefore, it is normal for economic variables to exhibit a nonlinear structure. Consequently, conducting analyses that account for this nonlinear structure is important for achieving more effective results. Kapetanios, Shin, and Snell (KSS) (2003) demonstrate that any nonlinear unit root test is more powerful than linear unit root tests. This study thus uses the test developed by Hepsağ (2021) for nonlinear unit root analyses. Furthermore, the fact that Hepsağ (2021) has proven that the unit root test is superior to other nonlinear tests, Kruse (2011) (Hepsağ, 2021: 629), is also a reason for choosing it as our analysis method.

This test is applied when breaks in economic time series are soft and can be modeled under the presumption of nonlinearity. A soft structural break is modeled via the logistic smooth transition function, whereas nonlinearity is modeled using the Exponential Smooth Transition Autoregressive (ESTAR) suggested by Kruse (2011).

Models allowing for a soft structural break to appear in the intercept term (α), in the existence of a time trend (β), and in both the constant term and the time trend (αβ) are shown in equations (3), (4), and (5) (Hepsağ, 2021: 626-627).

$$y_t = \alpha_1 + \alpha_2 S_t(\lambda, \boldsymbol{\mathcal{T}}) + v_t \quad (3)$$

$$y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\lambda, \boldsymbol{\mathcal{T}}) + v_t \quad (4)$$

$$y_t = \alpha_1 + \beta_1 t + \alpha_2 S_t(\lambda, \boldsymbol{\mathcal{T}}) + \beta_2 t S_t(\lambda, \boldsymbol{\mathcal{T}}) + v_t \quad (5)$$

In these equations, $S_t(\lambda, \boldsymbol{\mathcal{T}})$ denotes the logistic smooth transition function. The parameter λ represents the transition speed between the two regimes; $\boldsymbol{\mathcal{T}}$ represents the breaking point where the smooth structural break occurs; and t represents the time trend in the logistic smooth transition function. The initial step of Hepsağ's (2021) unit root test is based upon nonlinear estimation of the above models and the resulting residuals. In the second stage, assuming that the obtained residuals follow the ESTAR process suggested by Kruse (2011), the stationarity test is performed using equation (6) (Hepsağ, 2021: 627).

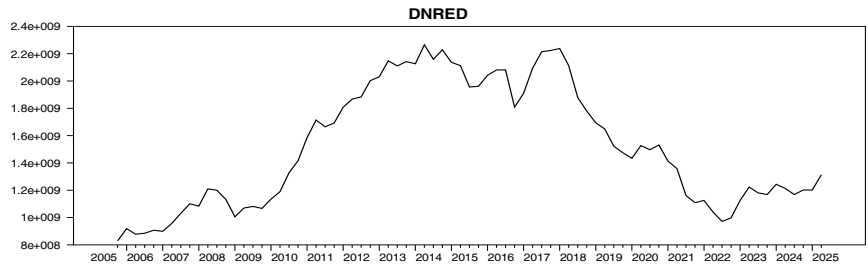
$$\Delta\hat{v}_t = \delta_1 \hat{v}_{t-1}^3 + \delta_2 \hat{v}_{t-1}^2 + \sum_{i=1}^{k} \alpha_i \Delta\, \hat{v}_{t-1} + \varepsilon_t \quad (6)$$

If the test statistics are smaller than the critical values obtained by Hepsağ (2021), H0, indicating a unit root, is not rejected. Otherwise, it shows ESTAR stationarity with a soft break.

IV. Applicatıon and Findings

When the graph of the discounted net real external debt stock in Türkiye (see Figure 1) during the period 2005:Q4-2025:Q2 is examined, it is considered that the model numbered (5), which follows a nonlinear course and allows the soft structural break to be realized in both the intercept term and the time trend (αβ), is more appropriate.

Figure 1: The Discounted Net Real External Debt Stock of Türkiye (DNRED)



The calculated test statistic of 3.841 is smaller than the critical value $\boldsymbol{\mathcal{T}}(\alpha\beta)$ = 12.621 at the 5% significance level, as reported by Hepsağ (2021). In this case, the null hypothesis is not rejected. Therefore, Turkey's discounted net real external debt stock series (DNRED) is not stationary according to the nonlinear ESTAR test, exhibiting a soft break. The break point, given as 0.33970, corresponds to the period 2012:Q2. These findings show that the external debt data series newly revised and published by the CBRT (2005:Q4-2025:Q2) is not stationary according to Hepsağ (2021)'s unit root test, i.e., it contains a unit root. This finding supports the evidence in the literature that Turkey's external debt is unsustainable, i.e., that debt overhang exists.

V. Concluding Remarks

The paper analyzes the sustainability of Türkiye's discounted net real external debt stock using the CBTR's new methodology and data. We have evidence of nonstationarity in the data (2005:Q4-2025:Q2) using Hepsağ's (2021) nonlinear ESTAR unit root test. This violates the sustainability condition expressed. Findings suggest that the Turkish external debt does grow without bound in the long term. That is to say, the country is insolvent. These findings indicate that the impact of shocks on external debt is permanent rather than temporary. In other words, the external debt variable is stationary, implying that the effects of real and monetary

shocks on the debt variable are temporary, i.e., they fade away and disappear over time.

Several points separate this work from others in the field. First, unlike many unit root tests in the field, this paper's test is based on a theoretical sustainability condition. Secondly, nonlinear unit root tests, which are more robust and account for breaks, are applied. Finally, the external debt stock series (2005:Q4-2025:Q2), calculated using new methods and data released by the CBRT on March 12, 2026, is used.

The empirical evidence suggests that Türkiye's discounted net real external debt stock exceeds the expected future payments. That is, Türkiye's current discounted net real external debt outstanding exceeds the predicted present value of future net primary surpluses, implying a debt overhang that undermines economic growth. This implies that Türkiye's external debt management strategy is unsustainable and should be revised. Based on the empirical evidence presented here, one can conclude that Türkiye's non-stop debt repayments during the period 2005:Q4-2025:Q2 cannot be sustained in the long term unless there exists a significant alteration in the external debt management strategy. In other words, Türkiye has long since surpassed the point where it can continue to operate a Ponzi scheme.

Findings also indicate that Türkiye's current account deficits are unsustainable, i.e., the country cannot fulfill its external debt liabilities in the long term without playing a Ponzi scheme. Therefore, external debt and current account management should be addressed together and in a coordinated manner; measures to prevent an unsustainable external borrowing strategy from undermining economic growth and prosperity should be given priority. Both the country's growth and current account policies need to be urgently reviewed. Only with successful growth and current account policies can the country's risk premium be reduced and its credibility and reputation increased.

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From Individual Health to Macroeconomic Outcomes: The Economics of Pandemic Shocks

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ABSTRACT

Health is a fundamental component of human capital that goes beyond individual well-being to serve as one of the key determinants of economic growth and development. It is increasingly recognized that economic growth cannot be explained solely by the accumulation of physical capital or technological advancements; it may also be closely linked to the quality of human capital and, in particular, to individuals' health status. Improvements in health stock support individual economic gains by increasing healthy life years and productive capacity, and these effects are also reflected in social welfare and macroeconomic performance. In this context, health is both a result of development and one of the key inputs for sustainable economic growth. Furthermore, the effects of improvements in health capital on individual and social well-being are becoming more pronounced, particularly in developing countries; this also underscores the importance of public policies aimed at protecting and promoting health in terms of their sustainability.

This chapter examines this relationship between health and macroeconomic performance within the framework of the health capital approach and assesses the micro-to-macro economic consequences of sudden disruptions in health stock through the lens of pandemic shocks, which are a type of health shock. Pandemics not only reduce the health stock and labor capacity of infected individuals; they also shape the behavior of uninfected individuals seeking to avoid health risks. Consequently, individual responses—beginning with labor supply, productivity, and consumption decisions—can spill over into production, income, employment, firm activities, investment, and supply chain relationships; a negative health-

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related shock can thus translate into macroeconomic and global costs through interconnected economic channels. This transmission process demonstrates that the economic costs of pandemics cannot be assessed solely through direct health losses and that there is a significant interdependence between individual health decisions and societal outcomes. In this context, the chapter demonstrates that pandemics have exposed not only the vulnerabilities of the health system but also the fragility of the macroeconomic system in the face of disruptions to health capital. It highlights the importance of differentiated optimal policy approaches by emphasizing the interdependence between policies addressing health risks and macroeconomic stability.

1. Introduction: Health as a Determinant of Human Capital and Improving Health Status

Economists have long recognized that individuals are an important component of a nation's wealth (Schultz, 1961). However, in economics, objectifying the individual and viewing them as human capital has the potential to become an incomplete line of argument that is ontologically and ethically problematic. Although values and beliefs may prevent viewing humans as capital, H. von Thünen noted that there is no degradation or disregard for freedom in interpreting the concept of capital as it applies to humans. A. Smith further developed the discussion by adding that the useful skills acquired by citizens can be viewed as part of capital (Schultz, 1961). According to the OECD (n.d.), human capital is concerned not so much with the individual as with the knowledge, skills, and personal characteristics that can support productivity. These qualities constitute an indivisible, non-transferable, and non-saleable stock of human capital inherent to the individual, thereby subjectifying the individual.

In the 1980s, many countries implemented stabilization and adjustment policies to resolve the macroeconomic imbalances they were experiencing and to achieve the goal of sustainable growth (World Bank, 1993). In the economic climate of the 1990s, various studies were conducted on economic growth models and their determinants, testing different variables; however, only a few variables were found to be statistically significant in explaining growth. One of the variables considered a driver of economic growth is human capital. While the new endogenous growth theories under discussion explain increases in human capital productivity through the determinants of education and technological development, the interaction between health and growth has received less attention in the literature (Barro, 1996).

Individuals value and seek good health. Therefore, the goal of achieving better health—rather than medical care itself—is a better indicator of well-being, even if it does not translate into an increase in income (Becker, 1962; Bleakley, 2010; Grossman, 1972). An individual's state of well-being is defined as "being healthy." Although there are many determinants that drive economic growth and development, health stands apart from other determinants in the literature because it is valuable in and of itself, given its ability to generate healthy time (Bloom et al., 2018; Weil, 2014). For example, unlike education, health develops as a result of multidimensional behavioral choices made from early childhood through old age. Individuals possess a health stock that decreases with age but increases with investment. Within this framework, the health stock can be enhanced through resources allocated to capital formation, such as medical care, diet, and exercise. In this context, by improving their mental and physical health, individuals can invest in human capital and also increase the total time spent on the production of money, goods, and services—which constitute the health stock—as well as their real income (Becker, 1962; Grossman, 1972). Thus, health is a determinant of human capital capable of creating value on its own through stock accumulation.

Health, in addition to creating value on its own right, is influenced by other determinants of human capital, such as education and technological development. These determinants have both direct and indirect effects on health status that contribute to increased well-being. Improved health has been achieved as a result of factors such as income growth, rising literacy and educational attainment, government investment in and expansion of health services, and technological advancements (World Bank, 1993). Improvements in health also have social effects, such as increasing school enrollment and learning ability (World Bank, 1993). Consequently, health also supports other determinants of human capital (Bleakley, 2010; Schultz, 1961). Governments have implemented indirect policies that influence the health system through public health measures such as education, water supply and sanitation, food regulations, and the regulation of insurance companies. Technological advancements in the health sector, public health programs, and public awareness campaigns regarding health also have the potential to support income growth by reducing mortality rates. These developments have facilitated income growth—particularly among the poor—through increased productivity and have positioned health as a durable good by generating additional income through health-related gains, thereby serving as a mechanism to improve consumption (e.g., food, housing, and health care) and create alternative savings (Strauss & Thomas, 1998; World Bank, 1993).

Since health depends on the resources allocated to an individual's productivity, it is viewed as a stock of human capital that can be enhanced by the individual, the

employer, or the government (Becker, 1962; Bleakley, 2010; Grossman, 1972). Investing in human capital—by developing relevant qualities in individuals that constitute their stock of human capital and may be regarded as resources – involves activities that affect earnings, consumption and future real income. (Becker, 1962). Although an individual's investment in themselves may appear to be reduced to a material component, it is also a means of creating welfare by increasing individual wealth. In this context, it is assumed that an increase in human capital boosts productivity in the market sector—by affecting wages and salaries—as well as in the non-market or household sector, where goods included in the utility function are produced (Grossman, 1972; Schultz, 1961). In short, human capital grows through investment in the individual and their health (Schultz, 1961). Consequently, improvements in health create a dynamic that yields benefits not only in terms of functionality and productivity but also at the individual, household, and societal levels (Strauss & Thomas, 1998).

Consequently, although an individual's health level may initially appear to be a micro-level issue, as a determinant of human capital, it will have positive or negative outcomes in the economic system that extend beyond individual health.

1.1 Health in Terms of Its Impact on Labor Market Dynamics

It is well known that improvements in health over the course of history have not only led to increased well-being but have also reduced the economic burden of unhealthy workers on the labor market. In this context, developments such as international health interventions, effective public health measures, and the introduction of new drugs since the 1940s have contributed to improved life expectancy (Acemoglu & Johnson, 2006). The years of life gained through these improvements are spent in better health and lead to a longer working life (Bloom et al., 2018). Improvements in health, rising life expectancy, and expanding production will provide greater incentives for the expansion of the stock of human capital. A notable point here is that health and income are interrelated. The relevant literature also supports this (Bleakley, 2010; Bloom et al., 2018; Strauss & Thomas, 1998; Weil, 2014). As income rises, individuals with greater access to better nutrition will invest more in their own health, support the development of the community's health infrastructure, and create a system that encourages governments to make greater investments in public health (Bleakley, 2010; Weil, 2014). Consequently, while health status is defined as a social goal with direct benefits in terms of a longer and better life, it is also closely linked to the success of the labor market and labor productivity as a stock of human capital (Acemoglu & Johnson, 2006; Bloom et al., 2019; Strauss & Thomas, 1998). Healthy

individuals in the workforce are more physically and mentally active and productive. Since they are less likely to experience illness or disability compared to other workers, absenteeism will decrease, labor productivity will increase, the likelihood of early exit from the workforce will decrease, and hourly wages will rise. Consequently, it is evident that the quality of human capital—and, in this context, a healthy life—is crucial for sustainable growth.

A healthy lifestyle encompasses various areas that employers, as well as individuals, can support. Investments that promote better health—such as medical examinations and lunch subsidies provided by employers, as well as measures to prevent workplace accidents or fatal incidents—will enhance the capacity of a healthy workforce. This development is an investment that will increase productivity; as a result, employers will have the opportunity to reduce costs that would otherwise place an additional burden on the production process with a healthier workforce, allocate more resources to employee training, and reap greater benefits from specialization (World Bank, 1993). Consequently, improvements in health supported by employers generally bolster labor productivity while also facilitating an increase in real output through the accumulation of capital (Bloom et al., 2004).

Developments such as the opportunity to achieve better nutrition through increased income improve worker health, thereby boosting strength, endurance, and earning capacity. The fact that employers also demand a healthy workforce—which will reduce their costs—creates a system that both promotes and rewards health by raising wages in the labor market. For example, export sectors in particular are willing to pay higher wages to hire skilled and healthier workers (Becker, 1962). In this context, a profile of healthier workers will emerge—one that is physically and mentally stronger and more productive, with a reduced likelihood of absenteeism due to illness or disability, and who, as a result, earn higher hourly wages by minimizing production losses. Improvements in working conditions, such as wage increases and enhanced benefits, will positively affect workers through improved morale and productivity by reducing the number of workdays lost due to illness (Becker, 1962; Bloom et al., 2004). Improvements in health will lead to longer working lives and increased productivity, creating opportunities to work in better-paying jobs and raising earnings. At the same time, it will allow resources originally earmarked for the treatment of illness or disability to be redirected to alternative uses. Conversely, a decline in health will affect economic performance due to its negative impacts on individuals, households, and resource allocation, and unhealthy workers will be excluded from the labor market because of the additional costs they impose on employers

(Strauss & Thomas, 1998; World Bank, 1993). In conclusion, improvements in health yield numerous benefits for both individuals and the market.

1.2 From Improved Health to Economic Development: The Role of Public Policy

It is evident that workers, as part of the labor market, can influence the system's efficiency through productivity. At the same time, every individual is a part of society, and healthy individuals will contribute to healthier societies. In this context, improving health is an area of responsibility shared by both employers and governments. Developing and low-income countries are at the center of growth and development strategies. This is because the disease burden resulting from poor health conditions in these countries hinders growth. In this context, health serves as both a goal and a fundamental input for growth and development (WHO, 2001). In particular, the employment structure of developing countries consists of a workforce engaged in jobs that require good health—primarily manual labor that relies more on physical strength and endurance compared to industrialized nations. However, the quality of human capital is lower compared to that in developed countries. This situation intensifies competition among countries at the level of development, thereby increasing inequality. In these lagging countries, improving the quality of human capital is crucial for supporting growth (Puig-Junoy & Pascual-Argenté, 2006). According to the literature, a major reason why many Black people, Mexican immigrants, agricultural workers, poor farmers, and elderly workers have low incomes stems from a lack of government investment in health and education. In this context, the negative impact of conditions such as illness or disability on income—as a cost to productivity—is felt more acutely in developing countries (Schultz, 1961; Strauss & Thomas, 1998; WHO, 2001).

While health standards are low in developing countries, the prevalence and nature of diseases also vary. In this context, while the likelihood of encountering such health problems as malnutrition or infectious diseases increases, the deterioration of health affects functionality thus leading to disability. At the same time, while adults in poorer countries face more health problems, it has been observed that some of these health problems originate in early childhood. The shift in the age distribution of health problems toward infancy or the preschool years results in the functional consequences of these problems being felt from childhood through old age (Strauss & Thomas, 1998). In this context, the literature places special emphasis on the importance of early childhood.

A large portion of human capital is formed in early life, and childhood plays a crucial role in its development. Damage caused by health-impacting factors—such as malnutrition, inadequate nutrition in utero, and childhood illnesses—will negatively affect human capital and lead to a reduction in lifetime earnings (Bleakley, 2010). Consequently, the negative consequences of poor health on the labor market will also increase exponentially; while the poor working in physically demanding jobs are more likely to face serious health problems, the wages they receive in exchange for their limited productivity will remain low. In this context, the budget they can allocate to medical care and treatment expenses will also be limited (Strauss & Thomas, 1998). In short, the increasing burden of disease and deteriorating health will exacerbate inequality among countries. Consequently, investments in health have the potential to create a positive impact on human capital, alter a country's production capacity limits, help it escape the poverty trap, and stimulate growth (Puig-Junoy & Pascual-Argenté, 2006). Therefore, their implications for health and the labor market are also significant from a public policy perspective.

Growth can also be measured using health indicators such as life expectancy and infant mortality rates, which reflect the quality of human capital (Bloom et al., 2018; Weil, 2014). In this context, the literature particularly emphasizes that aggregate indicators measuring health status—such as life expectancy—have a positive effect on growth and are predicted to be a better determinant of growth than education; a one-year improvement in life expectancy increases growth by 4% (Barro, 1996; Bloom et al., 2004). Similarly, a significant relationship has been found between income growth resulting from improvements in health and the child mortality rate; it has been observed that in countries where average income increases by 1 percent, the child mortality rate decreases by more than 50 percent. Consequently, health-improving economic policies implemented by governments to achieve sustainable growth and development are among the most important measures (World Bank, 1993).

Government support for investments in health care and contributions to building a healthier society will help reduce the costs of medical care and treatment. Even with low-cost interventions such as vaccination, antibiotics, and nutritional supplementation programs, there have been noticeable improvements in health outcomes. Consequently, governments view health spending as a cost-effective investment that pays for itself. In short, health investments will generate hundreds of billions of dollars in income growth, particularly in low-income societies (Bloom et al., 2019; WHO, 2001; World Bank, 1993). In this context, health investments made to improve health also account for a significant share of the public budget (Strauss & Thomas, 1998). As health improves, the rate of income

growth and labor force participation will increase, thereby boosting worker productivity. In this context, it is estimated that a 10% increase in adult survival rates would lead to an approximate 9–10% increase in labor force productivity. In addition to productivity, expenditures aimed at improving health and investments in health infrastructure will also support economic growth (Bloom et al., 2019; Strauss & Thomas, 1998). Furthermore, increased life expectancy will encourage investment in education, innovation, and physical capital, and will support the economic transition—particularly for women—from stagnant incomes to sustainable income growth.

As a key factor influencing development and accelerating growth, health is a social goal that yields direct benefits in terms of a longer and better life by enhancing well-being. In this context, improving health—a crucial aspect of human capital—is essential for achieving sustainable economic growth and development (Bloom et al., 2018). Consequently, while an increase in health expenditures is projected, it is emphasized that health expenditures and investments should be supported for economic reasons because they contribute to well-being (Weil, 2014; World Bank, 1993).

2. The Economic Impacts of Pandemics: Transmission Channels from a Health Shock to a Macroeconomic Shock

In the second section, pandemics are addressed as health shocks; the vulnerabilities they may create for the macroeconomic system are assessed through direct channels—such as the labor force, income, and productivity—as well as indirect transmission channels, including individuals' production and consumption decisions, firm activities, investments, supply chains, growth, and well-being.

Since the health stock is not a static entity, shocks that simultaneously affect public health pose a risk of spreading throughout the broader economic system. Health shocks are one of the factors that can lead to unexpected disruptions in the health stock. Over time, shocks that could affect the health stock may be economic, social, environmental, or epidemiological in nature. Furthermore, such shocks may manifest as sudden, short-term events or as long-term structural transformations.

Since health is a factor that directly and indirectly affects productivity as a determinant of human capital, the economic consequences of changes in the

health stock are evident in terms of both income, well-being, and production capacity, as well as growth performance. Changes in individual health status will affect factors such as labor productivity, income levels, labor force participation, productive capacity, health expenditures, production and consumption decisions, firm activities, supply chains, and growth (Bloom & Canning, 2000; Bloom et al., 2011). In short, individual health is becoming an integral part of social capital.

Pandemics are a specific form of public health shock that can simultaneously affect the health capital of a large population through various health risks, such as mortality and morbidity. Pandemics demonstrate that health shocks not only result in individual economic costs but can also generate unexpected macroeconomic costs through the channels to which they are linked. In this context, the goal of protecting individuals' health capital from any potential deterioration highlights the simultaneous losses caused by a pandemic as they ripple through the system via multiple channels. Consequently, pandemics take on the nature of a health shock that generates macroeconomic outcomes—primarily through the interplay of health and individual economic decisions. Ultimately, by testing the economic system's resilience to health shocks, they reveal the vulnerabilities of the macroeconomic system (Cotula, 2021; Leach et al., 2021). At the same time, even though it is a sudden and short-term health shock, it serves as a widespread example illustrating how disruptions spread from the micro to the macro level within the global economic system.

In a globalized world, pandemics affect the economy through numerous channels, from the micro to the macro level. First, one of the transmission channels through which pandemics directly affect the economy via human capital is the labor supply; they manifest as a shock that reduces both the quality and quantity of the labor force. A decline in the labor supply—due to illness, death, quarantine, or the emergence of household care responsibilities—directly leads to a loss of human capital through a reduction in the number of employed individuals and in working hours. Similarly, according to the International Labor Organization (2021), global working hours decreased by 8.8 percent in 2020, equivalent to 255 million full-time jobs. According to the ILO (2021), the full-time job equivalent is calculated as the sum of employment losses and the reduction in workers' hours.

The World Health Organization (2022) states that there were 14.9 million "excess deaths" directly or indirectly related to the pandemic, noting that health shocks have societal consequences that go beyond the loss of individual health capital. Excess deaths are defined as the difference between the total number of deaths—including both direct deaths caused by the pandemic and indirect deaths related to the strain on health systems or societal impacts—and the total number of deaths

that would have occurred had the pandemic not taken place. Indirect deaths—resulting from disruptions in medical care services for other illnesses and difficulties in accessing such services due to the excessive strain on the health system—also demonstrate the erosion of health capital. Both outcomes indicate that the simultaneous losses in human capital caused by the pandemic through the erosion of health capital will generate macroeconomic costs across the entire system.

The direct and indirect costs of infectious diseases—which cause pandemics—on the labor supply are typically examined in health economics studies on the burden of disease. The traditional approach relies on mortality or disability data to estimate future income losses; while past diseases provide important insights into how future diseases should be understood, they cannot fully reflect the true economic costs of highly contagious, epidemic-scale diseases (McKibbin & Fernando, 2020). Consequently, it is anticipated that the macroeconomic costs generated by infected individuals cannot be fully determined in advance.

A pandemic is not merely a risk that affects infected individuals—whose health capital is directly impacted—and the labor supply process; it also constitutes a process that shapes the future consumption decisions of uninfected individuals. From this perspective, during the pandemic, individuals are also taking actions to protect or enhance their health stock, which constitutes their human capital. Just as the disease affects the economy through the labor supply, the behavioral consumption decisions individuals make regarding issues such as the risk of exposure and transmission also shape the pandemic's effects.

In the economic system, individuals produce and consume. During the pandemic, this situation creates conditions that accelerate the spread of the virus due to social contact and the risk of infection. In this context, fear emerges as a factor that shapes individuals' consumption behaviors and reduces economic activity during the pandemic. Fear of an unknown, deadly disease, in terms of its psychological effects, is similar to the response to terrorist threats and typically causes a high level of stress that leads to long-term consequences. In this context, in an environment where health risks are heightened, individuals will reduce both their labor supply and their consumption; consequently, individual pandemic precautions will also lead to an economic contraction. It is also known that the likelihood of the disease spreading has led to mandatory lockdowns and travel restrictions in countries (McKibbin & Fernando, 2020). However, while government-imposed measures such as lockdowns and social distancing are a cause of the economic contraction, the avoidance of activities requiring physical contact—driven by the pandemic itself and the fear it generates—is also a

significant factor. Eichenbaum et al. (2021) also demonstrate that the decision to reduce consumption and work lowered the severity of the pandemic and the number of deaths but exacerbated the economic recession through the supply and demand channels. In short, the health stock—which is sought to be protected within the context of individuals and human capital—has become a variable that is both affected by the pandemic and influences its progression. In this context, micro-level decisions made to protect the health stock during the pandemic can affect macro-level channels such as economic growth.

Given the health risks and uncertainty arising from the pandemic, individual demand for goods and services has not declined uniformly. In this context, the level of physical contact required for consumption shapes economic decision-making. Activities in sectors where physical contact is high—such as lodging, tourism, education, food and beverage services, transportation, sports, entertainment, and culture—are more sensitive to health risks. Consequently, both labor supply and consumption losses are greater in these more sensitive sectors. At the same time, due to sectoral differences, the severity of consumption losses for firms and individuals will also vary. A study by Chetty et al. (2024) on the United States found that high-income individuals significantly reduced their spending during the COVID-19 pandemic, and 57 percent of this spending was related to activities involving high levels of physical contact, such as hospitality, transportation, and food services. These spending cuts reduced small business revenues and increased unemployment among low-wage workers. In this cycle, workers who suffer income losses due to supply constraints in any sector can also negatively affect spending, production, and employment in other sectors where no such supply constraints exist. In their study, Guerrieri et al. (2022) highlighted this cycle and examined, within their model, the conditions under which a contraction in demand in certain sectors could exceed the related supply shock, defining this as a "Keynesian supply shock."

The pandemic's impact on productive capacity and productivity—as part of the human capital component, namely the health stock—directly leads to a loss of production through a decline in the labor supply, while the inability to efficiently combine factors of production and disruptions in the production process also affect business productivity. It is noted that, in addition to related firm-level technical setbacks, productivity transfers also occur among firms through the reallocation of labor and production factors.

In their study, Bloom et al. (2025) examined the impact of the COVID-19 pandemic on productivity through the lens of total factor productivity in the private sector. The study indicates that total factor productivity declined due to

firm-level productivity losses. Although there was a reallocation of productivity from less productive firms to more productive ones, the study indicates that the loss in firm-level productivity could not be fully offset. Consequently, it is anticipated that organizational processes—such as the way businesses operate, the redesign of business processes, and changes in the composition of the workforce—will be reshaped over time.

The international fragmentation of production—due to differences in costs, specialization, and technological capacity—is leading to the global spread of the pandemic's local economic impacts. In particular, disruptions in local production in any given country—especially for goods and services that are part of the global supply chain—will also affect production in other countries. A country whose production is indirectly affected will experience the economic impacts of the pandemic—albeit indirectly—through the global supply chain. The COVID-19 pandemic has caused contractions in production in other countries around the world owing to disruptions in production and the global supply chain in China. Furthermore, restrictions on international travel have slowed economic activity. The panic experienced by consumers and businesses has disrupted consumption patterns, leading to market anomalies. Global financial markets have also reacted negatively to these developments, and stock market indices have fallen (McKibbin & Fernando, 2020).

In their study, Bonadio et al. (2021) examined the role of global supply chains in the pandemic-induced losses in GDP using a 64-country model; they found that one-fourth of the total decline in real GDP was attributable to spillovers between countries and sectors via global supply chains. They also note that while localizing all stages of the production process may limit real GDP losses in the face of global health shocks, it will not make a country more resilient to the effects of a pandemic. However, increased reliance on domestic suppliers may also affect resilience in the event of new local health shocks. Therefore, sustainable measures—such as establishing alternative supply channels, increasing the use of substitute inputs, and strengthening production networks against health shocks—are of great importance.

In conclusion, the economic effects of pandemics create a process that begins with a local or sectoral labor supply shock and can evolve into a contraction in aggregate demand. Consequently, the response to the health risks posed by the pandemic affects not only production and consumption but also macroeconomic variables such as income and employment, potentially exacerbating inequalities in the labor market and impacting the macroeconomic system through direct or indirect transmission channels.

3. General Assessment and Policy Recommendations

Health shocks, which can simultaneously affect public health through individual health, prompt individuals to take concurrent actions to manage health risks and preserve their health capital. These actions generate associated costs over the long term, either directly or indirectly, through numerous economic transmission channels. In this context, health—as one of the determinants of human capital—is crucial for addressing macroeconomic vulnerabilities and ensuring economic growth. Sudden health shocks, such as a pandemic, demonstrate that many economic channels—from the micro to the macro level—are interconnected and have a fragile structure. Consequently, a process emerges in which health shocks like a pandemic can threaten growth and macroeconomic stability. The spread of the pandemic from micro to macro channels could generate not only the direct costs of the infectious disease but also overall macroeconomic costs. In short, global health crises such as the pandemic should not be assessed solely based on the costs incurred through directly infected individuals. At the same time, uninfected individuals also shape their economic decisions and behaviors with the aim of improving or protecting their health capital. In this context, it should also be noted that they can generate various macroeconomic costs by influencing developments in channels such as firms' production, investment, and employment decisions, as well as production and trade linkages between firms and sectors.

Although voluntary individual decisions and behaviors during the pandemic may partially limit the spread and severity of the pandemic, market equilibrium may not yield a socially Pareto-optimal outcome. Even though individuals believe they are making economic and social decisions that appear rational, a situation is emerging in which individual decisions may not be socially optimal and market decisions may generate "infection externalities." When making decisions, individuals will consider their own health risks, consumption benefits, and income losses but they will not fully account for social costs such as transmitting the disease (Bethune & Korinek, 2020; Eichenbaum et al., 2021). In this context, it is evident that a health shock capable of affecting health capital has the potential to transform into a simultaneous global macroeconomic shock.

The fact that simultaneous macroeconomic and social costs arise as individuals strive to protect their health capital provides the economic justification for public intervention in the face of a global health shock. Consequently, interventions that reduce the risk of contact and transmission—such as testing, social distancing, isolation, stay-at-home orders, paid sick leave, and free vaccination—are important not only for protecting individual health but also as market failure corrections that reduce economic and social costs (Bethune & Korinek, 2020;

Eichenbaum et al., 2021). However, there is also debate over whether the public interventions implemented during the pandemic are effective.

It is noted that, in addition to government-mandated lockdowns, changes in individual consumption behavior also played a major role in the decline in economic activity during the pandemic (Goolsbee & Syverson, 2021). Consequently, it is anticipated that economic costs would arise even in the absence of government intervention. However, while governments' efforts to protect public health and reduce the transmissibility of the pandemic through public policy measures curtail economic activity, it is also important to note that prolonged restrictions can impose significant costs in terms of income, employment, education, and mental health. These costs will pose obstacles to both health and growth objectives. Therefore, an effective policy must be designed—taking into account the economic and social costs—to determine the scope, timing, and distribution of measures that can reduce transmission while normalizing systems, particularly the healthcare system.

Just as there are differences in health capital between infected and uninfected individuals, individuals with varying levels of health capital among the uninfected population also face different health risks. Consequently, it is believed that the impact of one-size-fits-all public policy measures aimed at preserving health capital and improving health may be limited. Acemoglu et al. (2021) also observed that pandemic risk is distributed heterogeneously across the population and highlighted the importance of differentiated optimal policies. In this context, it has been noted that optimal policies tailored to different age and risk groups may be more effective in improving the balance between health and economic losses than one-size-fits-all policies that impose the same restrictions on the entire population. It has been projected that economic policies aimed at public health could achieve higher performance by tightening measures for older age groups with more vulnerable health and applying less restrictive measures to low-risk groups.

In conclusion, the productive capacity and health stock of the health system are components of macroeconomic resilience, and the economy interacts with health policies. Therefore, rather than choosing between a complete restriction of economic activity and the absence of any public intervention, the transmission externalities created by the pandemic should be mitigated. Health policies should be developed to mitigate economic losses in channels such as the labor force, production, consumption, and trade. According to the approach of Acemoglu et al. (2021), targeted policies applied to a population with varying health risks are expected to yield better results. In this context, it is also anticipated that different

macroeconomic costs will arise due to the differentiation of channels through which individuals' health risks are transferred to the economic system. As a matter of public policy, it is suggested that the development of health policies differentiated according to the population's health risk be considered. It is believed that costs in both the health care system and the economic system could be minimized in this context. However, rather than treating this outcome as a definitive policy prescription, it is anticipated that adopting a perspective that considers factors such as health risk, forms of economic activity, and feasibility—among others—could yield better results.

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New Era of Energy Geoeconomics Restructuring Energy Security and Türkiye's Energy-Trade Nexus

Mert Can Duman[1]

Abstract

Modern energy systems are entering a new geoeconomic era in which the sources of strategic power are shifting from the ownership of fossil-fuel resources toward control over the networks, technologies, infrastructures and value chains that make energy systems function. Both green and digital transformation, combatting the climate change, electrification, geopolitical rivalry and changing patterns of international trade are simultaneously reshaping the structure of energy security. In this regard, this chapter mainly argues that the energy transition should therefore not be understood simply as a substitution of hydrocarbons with renewable energy, but as a fundamental reconfiguration of global interdependence.

To capture this transformation, the chapter develops the concept of Energy Security 2.0, which conceptualizes contemporary energy security as a systemic capability built upon three interconnected dimensions: supply security, supply-chain security and trade security. While conventional energy security focused predominantly on the physical availability and affordability of fuels, the emerging system increasingly depends on critical minerals, processing and refining capacities, manufacturing capabilities, electricity grids, storage systems, technological knowledge, financial resources, logistics and trade networks. Energy security consequently becomes increasingly relational and network-based:

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strategic vulnerability may arise not from the absence of resources themselves, but from dependence on critical nodes within global value chains.

The chapter also examines this transformation through a comparative analysis of major international actors. Different cases demonstrate that the energy transition redistributes rather than eliminates geopolitical and macroeconomic vulnerabilities. Particular attention is devoted to Türkiye, whose strategic significance increasingly derives from geographical connectivity, energy infrastructure, market integration, diversification capacity and diplomatic reach rather than resource ownership alone. The chapter argues that Türkiye's long-term trajectory should move beyond the conventional concept of an energy corridor toward a regional energy and trade platform connecting resources, markets, technologies and industrial value chains. Ultimately, the chapter contends that the emerging energy order will be shaped not by the elimination of interdependence, but by the capacity of states to transform interdependence into resilience, economic value and geoeconomic power.

The global energy transition is therefore not eliminating geopolitical interdependence but restructuring it. The comparative analysis in this chapter demonstrates that future geoeconomic power will increasingly depend on the ability to manage these strategic interdependencies. For Türkiye, this transformation creates an opportunity to move beyond the role of an energy corridor and emerge as a regional platform connecting energy, trade, infrastructure and industrial value chains.

Keywords: Energy Geoeconomics, Critical Minerals, Geoeconomics, Energy Trade, Global Value Chains, Türkiye, Energy Diplomacy.

1. Introduction

Today, energy occupies a distinctive position in the global economy. In modern economic structure, it is simultaneously an economic input, a strategic commodity unlike other commodities whereas it is also a geopolitical instrument and an environmental challenge. Energy could be defined as, moreover, a determinant of household welfare, a source of macroeconomic vulnerability, a strategic asset and an essential component of national security. From manufacturing to transportation, agriculture to logistics, digitalization to infrastructure; disruptions in energy markets can propagate rapidly through production costs, inflation, investment decisions, external balances and economic growth.

The macroeconomic importance of energy is particularly evident when prices are volatile. A sudden increase in oil or natural gas prices can simultaneously raise production costs, increase consumer prices, worsen the trade balance of energy-importing countries and reduce household purchasing power. Hamilton's (2009) analysis of the historical relationship between oil shocks and recessions illustrates the extent to which energy-price disruptions can influence macroeconomic performance. More recent research has likewise emphasized that energy-price shocks can affect inflation through both direct energy costs and indirect production-cost channels. Recently, the energy-price shock following Russia's invasion of Ukraine and increasing geopolitic tension in Hormuz again demonstrated the extent to which energy dependence can translate into inflationary and fiscal pressures across economies.

Energy security has therefore traditionally been understood as the ability of an economy to obtain sufficient quantities of energy at acceptable prices and with a reasonable degree of reliability. This understanding emerged particularly strongly following the oil crises of the 1970s, when disruptions in oil supplies demonstrated that energy could become a source of macroeconomic and geopolitical vulnerability. Over time, however, the concept expanded. Sovacool and Mukherjee (2011), for example, identified availability, affordability, technology development, sustainability and regulation as five broad dimensions of energy security. Cherp and Jewell (2014) subsequently argued that energy security should be understood in terms of the vulnerability of vital energy systems rather than simply the availability of fuels. Their approach is particularly relevant to the contemporary energy transition because it shifts analytical attention from individual resources to the systems through which energy is produced, transported and consumed. Additionally, Yergin (2006) emphasizes diversification of supply, resilience of infrastructure, market stability and the protection of key transportation routes as central components of energy security. As energy systems became more complex, however, scholars increasingly questioned whether energy security could be adequately captured through the availability of fuels alone. Sovacool and Mukherjee (2011) develop a multidimensional framework incorporating availability, affordability, technology development, sustainability and regulation, demonstrating the conceptual breadth of contemporary energy security.

The actual energy transition contains a further layer of complexity. Climate change mitigation requires a substantial reduction in greenhouse gas emissions, and the energy sector is central to this transformation. The Intergovernmental Panel on Climate Change (IPCC, 2022) identifies rapid decarbonization of electricity generation, electrification, energy efficiency and the deployment of

low-carbon technologies as essential elements of credible mitigation pathways. Yet decarbonization is not simply a process of replacing coal, oil and natural gas with solar and wind power. It involves the transformation of the material, technological and infrastructural foundations of the energy system itself.

An economy that reduces its reliance on imported oil and natural gas may simultaneously become more dependent on imported batteries, solar photovoltaic modules, wind-turbine components, electricity-grid technologies or critical minerals. Energy security is consequently moving from a relatively simple question of securing fuel supplies towards a much more complex question of securing the systems, technologies, materials and trade networks through which energy is produced and consumed.

As it is well known that the traditional energy system was built around fuels that could be extracted, transported, stored and burned. The emerging energy system is increasingly built around electricity, networks, storage technologies, digital systems and mineral-intensive technologies. The strategic importance of the system is therefore moving from the security of fuels alone towards the security of energy systems and their underlying value chains. This transformation is already visible in global energy investment. The International Energy Agency (IEA, 2025a) estimates that global energy investment is set to reach approximately USD 3.3 trillion in 2025, with around USD 2.2 trillion directed towards clean energy technologies, including renewables, grids, battery storage and electric vehicles, compared with approximately USD 1.1 trillion in fossil-fuel investment. In other words, clean-energy investment is now roughly twice the scale of fossil-fuel investment (IEA, 2025a).

Global electricity demand increased by 4.3% in 2024, substantially above global GDP growth of 3.2%. Around 80% of the growth in global electricity generation came from renewable energy and nuclear power, while renewable energy alone accounted for almost three-quarters of the increase in generation. Global renewable capacity additions reached approximately 700 GW in 2024, with solar PV accounting for more than three-quarters of new renewable capacity (IEA, 2025b).

Since the energy transition is no longer a distant environmental project; this transformation generates a paradox. The energy transition reduces some traditional vulnerabilities while creating new ones. An economy that reduces its dependence on imported oil and gas may simultaneously become more dependent on imported lithium, graphite, cobalt, nickel, copper or rare earth elements. A country may reduce its exposure to fossil-fuel price volatility while increasing its

exposure to concentrated technology and mineral supply chains. The geography of energy security is therefore changing.

The central argument of this chapter is that energy security is not disappearing in the energy transition; it is being reconfigured.

2. Energy Macroeconomics: Why Energy Security Matters for the Global Economy

Energy has a distinctive role in macroeconomic dynamics because it enters virtually every stage of production either directly or indirectly. Transportation, manufacturing, agriculture, construction and services all depend upon energy inputs. Consequently, changes in energy prices can propagate through the economy well beyond the energy sector itself. The classical example is the oil-price shock. Hamilton (2009) demonstrates that major oil-price increases have historically been associated with significant downturns in the United States, particularly because oil-price increases affect consumption, investment and production simultaneously. Although the structure of contemporary economies differs considerably from that of the 1970s, the underlying mechanism remains relevant: energy-price shocks can function as economy-wide supply shocks.

For energy-importing economies, the external-sector channel is particularly important. An increase in the international price of oil or natural gas increases the import bill, potentially worsening the current account and increasing demand for foreign currency. If the domestic currency depreciates simultaneously, the domestic-currency cost of energy imports can rise even more sharply. Energy prices can therefore interact with exchange-rate dynamics, inflation and monetary policy.

This relationship creates a particularly important challenge for emerging-market economies. Their industrialization strategies frequently depend on energy-intensive sectors, while their domestic energy production may not be sufficient to satisfy rapidly increasing demand. Energy imports can therefore become a structural component of their external vulnerability.

Energy security and macroeconomic stability consequently have a mutually reinforcing relationship. Unlike fossil fuel generation, which demands continuous expenditure on fuel subject to international market volatility, renewable energy technologies require higher upfront capital investment but operate with virtually zero fuel costs, providing long-term economic resilience through predictable production costs, reduced inflation vulnerability, greater investment certainty, and

enhanced industrial competitiveness. This creates a potentially important macroeconomic distinction between fuel-price exposure and capital-cost exposure.

Increasing reliance on domestic renewable generation can therefore reduce an economy's exposure to international fossil-fuel price volatility. However, it does not eliminate external dependence. Renewable technologies themselves require internationally traded minerals, components and manufacturing inputs. The vulnerability is therefore shifted rather than necessarily eliminated. For this reason, the transition in energy economics reaches far beyond national utility grids. As commodity reliance yields to capital investment, the ripple effects spill directly into global trade channels—reshaping national terms of trade, balance-of-payments vulnerabilities, and industrial competitiveness on the world stage.

3. Upgrading Energy Security from 1.0 to 2.0: Fossil-Fuel Security vs. Systemic Energy Security

For much of the twentieth century, energy security was fundamentally associated with fossil-fuel security. Oil, natural gas and coal constituted the dominant energy carriers, and international energy relations were shaped by the geographical concentration of fossil-fuel reserves. This structure produced a distinctive geography of international power. Large energy consumers were often geographically distant from major resource-producing regions. The international energy system therefore depended upon long-distance transportation infrastructure, including pipelines, tanker routes, ports and strategic maritime chokepoints.

The geographical concentration of oil reserves in particular contributed to the geopolitical importance of the Middle East, while natural-gas trade generated strategic interdependence between producers and consumers connected through pipelines and LNG infrastructure. This system did not disappear with the rise of renewable energy. Instead, its logic is being modified. Likewise, the literature also increasingly treats energy transition as a geographical process rather than a technological substitution. Bridge et al. (2013) argue that low-carbon transitions involve a reconfiguration of spatial relationships, economic activity and political authority. Their analysis highlights concepts including location, territoriality, spatial differentiation, scaling and spatial dedication, demonstrating that the geography of the future energy system could not be understood solely through the distribution of natural resources.

In the conventional era, energy security could be related to answering where the energy resources are located whilst meaning of energy security is changed in modern era such that where the critical nodes of the energy system are located, and these are not definitely the same. To exemplify, a country might possess significant lithium reserves but have limited influence over global battery markets if lithium is exported in raw or semi-processed form. Another country might possess limited mineral reserves but exercise substantial influence because it controls refining, processing or battery manufacturing. This distinction between resource endowment and value-chain centrality is becoming increasingly important, and the energy transition therefore changes the geography of dependence.

The importance of this systemic perspective is illustrated by critical minerals. According to the IEA (2025e), the average share of the world's top three refining countries for key energy minerals increased from approximately 82% in 2020 to 86% in 2024. More importantly, around 90% of the growth in refined supply during this period came from the single largest supplier, principally Indonesia for nickel and China for cobalt, graphite and rare earth elements (IEA, 2025e),

The issue is therefore not simply whether sufficient quantities of minerals exist globally. It is whether sufficient quantities can be extracted, processed, refined and delivered through diversified and resilient supply chains. This is why the concept of energy security 2.0 should incorporate at least four systemic dimensions: energy resources, mineral inputs, technological capabilities and international trade. The global economy is passing through a historical threshold marked by fundamental transformations in energy production and consumption patterns. Historically, the causal relationship between economic growth and energy consumption has been dominated by fossil fuels. Oil provided mobility, natural gas supplied flexible power generation and industrial heat, while coal served as the backbone of industrialization and power generation. However, driven by climate policies and technological innovation, economies are accelerating toward an "age of electricity."

Firstly, this dynamic is primarily driven by the escalating imperative to mitigate global climate change, which has transformed decarbonization from an environmental objective into a fundamental macroeconomic priority. Anthropogenic greenhouse gas emissions, overwhelmingly generated by the combustion of fossil fuels, have triggered accelerated warming trends, extreme weather events, and severe ecological disruptions that pose systemic risks to global economic stability (Intergovernmental Panel on Climate Change (IPCC), 2023; Stern, 2007). In response, international climate agreements—most notably

the Paris Agreement's commitment to limiting global temperature increases to well below 2°C above pre-industrial levels—have institutionalized carbon constraints through aggressive national emissions reduction targets, carbon pricing mechanisms, and net-zero commitments (Nordhaus, 2019; United Nations Framework Convention on Climate Change [UNFCCC], 2015). Because the power sector represents the largest single source of global carbon dioxide emissions while simultaneously offering the most technologically viable pathway for rapid decarbonization, replacing fossil-based generation with zero-carbon energy sources has become the foundational prerequisite for systemic climate mitigation (Azevedo et al., 2021; Rockström et al., 2017). Consequently, climate policies are forcibly reallocating capital away from fossil infrastructure toward low-carbon technologies, positioning deep electrification as the central engine of the global energy transition (Davis et al., 2018).

Electricity is no longer just a secondary energy carrier operating alongside primary fuels; it has become the core infrastructure upon which industrial production, transport, heating, digital infrastructure, and data centers are built. Electric vehicles (EVs) replacing petroleum consumption, heat pumps substituting for gas and oil, green hydrogen production transforming water through electrolysis, and the exponential growth of artificial intelligence infrastructure all substantiate this structural shift. According to the International Energy Agency, global electricity consumption increased by approximately 1,080 TWh in 2024—nearly double the average annual increase of the preceding decade (2025b). China accounted for the largest absolute increase, while clean energy sources fulfilled over 80% of this global demand growth (IEA, 2025b).

This transformation redefines the macroeconomic dynamics of energy and the fundamental meaning of energy "affordability." In a fossil-fuel economy, affordability is heavily dictated by volatile international oil and gas prices. In an increasingly electrified economy, affordability depends on generation costs, transmission, storage, grid expansion, and the capital cost of energy infrastructure. Consequently, for developing economies in particular, energy security becomes intrinsically linked to financial security. Even where renewable resources are abundant, countries facing high financing costs (cost of capital) struggle to deploy generation capacity, grid infrastructure, and storage, leaving them vulnerable to external shocks.

Building a resilient energy system is a structural determinant of macroeconomic stability and international competitiveness. A resilient energy infrastructure delivers key macroeconomic advantages such as reduced exposure to international commodity-price volatility, greater predictability of production costs, improved

external-balance resilience, reduced inflationary vulnerability: Mitigation of imported cost-push inflation, and stronger industrial competitiveness.

Fossil-fuel power generation entails continuous fuel expenditure throughout the operational lifespan of a plant: coal, oil, and natural gas must be continually extracted, transported, and purchased. Renewable energy technologies, by contrast, feature a fundamentally different cost structure: they require high upfront capital expenditure but operate with minimal running fuel costs. Once operational, the energy input is not purchased on volatile global markets. This situation directly intersects the macroeconomics of energy with international trade. Energy security ceases to be a metric of internal system efficiency; it becomes a geoeconomic lever shaping current account balances, exchange rate dynamics, and long-term comparative advantages in global markets.

While the expansion of renewable energy diversifies the geographical distribution of energy generation, it would be misleading to conclude that it eliminates energy geopolitics. Unlike fossil-fuel reserves, which are geographically concentrated in specific regions, solar and wind resources are widely distributed across the globe. This grants historically import-dependent countries the opportunity to expand domestic production and reduce geopolitical vulnerabilities. However, the literature emphasizes that renewable energy does not eliminate geopolitics; rather, it transforms the channels and objects through which geopolitical and geoeconomic influence is exercised. O'Sullivan et al. (2017) highlight the transformative geopolitical consequences of renewable energy, noting that structural influence shifts from resource owners to technological and infrastructure leaders where Overland (2019) cautions against deterministic arguments, challenging four widespread assumptions—namely, that critical minerals will automatically recreate petroleum-style conflict, that renewables will reproduce the resource curse, that electricity interdependencies will inevitably generate coercive leverage, or that renewables automatically increase cybersecurity threats. Vakulchuk et al. (2020), furthermore, demonstrate that while renewable energy mitigates traditional fossil-fuel dependence, it simultaneously generates new questions and dependencies concerning technology, infrastructure, and raw material supply chains. The core issue is hence not whether renewable energy is "geopolitical," but how the geography of geopolitical power changes when dominant energy technologies change. Modern influence is exercised through manufacturing scale, mineral refining capacity, grid integration, intellectual property, international standard-setting, and supply-chain concentration.

In addition to these, the energy transition is also fundamentally a "materials transition." The move toward electric mobility, renewable electricity generation, battery storage, and expanded electricity grids demands massive quantities of minerals and metals. Lithium, nickel, cobalt, graphite, copper, and rare earth elements (REEs) have consequently acquired paramount strategic importance. The IEA's Global Critical Minerals Outlook 2025 underlines that critical minerals have become central to both energy-transition strategies and broader industrial and trade policy debates (IEA, 2025e). Under its Stated Policies Scenario (STEPS), demand for lithium is projected to increase approximately fivefold by 2040, while demand for graphite and nickel will roughly double, alongside substantial growth in cobalt and rare earths (IEA, 2025e). This evolution introduces a vital distinction between geological availability and security of supply. A mineral may be geologically abundant worldwide, yet generate acute supply-chain vulnerabilities if extraction or processing is geographically concentrated. The strategic problem is therefore not necessarily scarcity in the conventional sense, but concentration. Mining and refining are frequently geographically separated. A country may possess vast geological deposits without the downstream industrial capacity required to transform raw minerals into inputs suitable for advanced manufacturing. As minerals move downstream along the value chain, strategic leverage increases significantly. Consequently, contemporary debates over critical minerals must move beyond asking who possesses the largest reserves to address; who controls processing and refining capacity, who controls advanced technology and component manufacturing, and who controls logistics and access to major consumer markets? The transition from Energy Security 1.0 (fuel-focused) to Energy Security 2.0 (technology and material-focused) is most apparent in critical mineral processing. Refining capacity exhibits significantly higher geographical concentration than raw mining.

At this point, China's dominant position in critical minerals does not stem simply from having geological reserves. Its strength derives primarily from its concentration of refining, processing, component manufacturing, and integrated industrial ecosystems. According to the IEA, China remains the dominant refined supplier for almost all key energy minerals (2025c). Similarly, for rare earth refining, the top three refining countries accounted for 97% of global capacity in 2024 and are projected to retain a 92% share in 2030 under stated policies (IEA, 2025d). This absolutely exposes a central paradox of the new energy economy: Renewable technologies diversify the geographical distribution of energy generation while simultaneously concentrating the industrial capabilities and refining capacities required to produce those technologies.

To sum up, the electrification of economies and the transition to renewable energy offer substantial macroeconomic benefits, reducing fuel-import expenditures, enhancing external balance resilience, and stabilizing production costs. The continuous commodity purchases characteristic of fossil-fuel dependence is replaced by capital-intensive renewable assets with low running costs. This structural transformation, however, does not eliminate geopolitics; it redistributes geoeconomic influence across different stages of the industrial value chain. Whereas the fossil-fuel era linked power to resource ownership and chokepoint control, Energy Security 2.0 ties influence to technological leadership, manufacturing scale, mineral processing, and supply-chain oversight. For policymakers, the core implication is clear: Energy security can no longer be achieved through the diversification of fuel suppliers; countries must proactively diversify industrial value chains and processing capacities. Reducing capital costs for energy investments, building international refining partnerships, and scaling recycling technology represent the key strategic imperatives for the modern era.

Traditional energy security paradigms were largely constructed around the physical availability and price stability of fossil fuels, particularly crude oil, natural gas, and coal, as reflected in foundational energy literature (Yergin, 2006; Winzer, 2012). However, ongoing structural shifts—namely decarbonization, rapid electrification, and the expansion of renewable energy systems—are fundamentally altering the nature of state vulnerability and market architecture (Johansson, 2013; Overland, 2019). In contemporary international political economy and energy economics, energy security can no longer be conceptualized as a single, static variable measured purely by import dependency or reserve-to-production ratios (Kruyt et al., 2009; Chester, 2010). Instead, it should be understood through the lens of multidimensional, systemic resilience across interconnected domain layers (Cherp & Jewell, 2014; Sovacool & Mukherjee, 2011). To comprehensively evaluate contemporary energy security architectures, this chapter advances an integrated analytical framework comprising three interconnected dimensions: supply security, supply-chain security, and trade security.

The primary dimension, supply security, concerns the physical availability of sufficient energy to meet the operational demands of households, industrial actors, and state institutions. In the conventional hydrocarbon era, this dimension focused almost exclusively on maintaining uninterrupted access to fossil fuel stocks and preventing volume disruptions from foreign producers (Bohi & Toman, 1996; Stern, 2007). In an increasingly electrified energy system, however, supply security expands to encompass electricity generation capacity, grid reliability, energy storage infrastructure, real-time system balancing, and the availability of

flexible generation assets (Azevedo et al., 2021; Jenkins et al., 2018). Consequently, the energy transition broadens rather than eliminates the supply security challenge, shifting the operational risk profile from volumetric fuel shortages to systemic power grid instability (Blazquez et al., 2018; Helm, 2002). A state may possess substantial domestic renewable potential, such as abundant solar or wind resources, yet remain energy-insecure if it lacks adequate high-voltage transmission networks or utility-scale storage capacity to manage resource intermittency and duck-curve demand dynamics (Denholm et al., 2015; Weber, 2012). Similarly, high installed generation capacity does not guarantee resilience if the power grid is vulnerable to extreme weather events exacerbated by climate change, cyberattacks targeting critical infrastructure, structural engineering failures, or insufficient operational flexibility (Panteli & Mancarella, 2015; Ten et al., 2010). Supply security has thus become intrinsically systemic, demanding continuous integration between resource endowments and physical network resilience (Bompard et al., 2013).

The second dimension, supply-chain security, shifts the analytical focus to the resilience of the industrial, technological, and logistical networks that convert raw natural resources into functional energy infrastructure and clean technologies. This dimension spans mineral extraction and processing, specialized manufacturing capacity, transport logistics, technological capabilities, and broader industrial ecosystems. Supply-chain security has emerged as a paramount geopolitical and economic consideration because the clean energy transition relies on highly specialized and geographically concentrated production value chains (Vakulchuk et al., 2020; World Bank, 2023). Disruption at a single upstream node can trigger severe downstream vulnerabilities across multiple economic sectors. For instance, bottlenecks in the refining of critical raw materials, such as lithium, cobalt, graphite, or rare earth elements, directly impair battery cell manufacturing capacity (IEA, 2025c; IEA, 2024b). Deficits in specialized components or semiconductor chips subsequently impair the production of electric vehicles and wind turbine powertrains (Pistilli, 2020; Sun et al., 2022). Ultimately, these cascading delays in clean-technology deployment derail broader national decarbonization trajectories and economic competitiveness (Hafner & Tagliapietra, 2020). The vulnerabilities associated with modern energy transitions are therefore systemic rather than commodity-specific, reflecting structural reliance on industrial processing monopolies rather than simple geographical resource locations (Gunderson et al., 2020; Seaman, 2019).

The third dimension, trade security, involves the ability of energy commodities, critical minerals, intermediate components, and clean-tech equipment to traverse international markets via stable, predictable, and diversified trade channels.

Because no single economy possesses all the natural deposits, refining capacities, manufacturing hubs, and technological capabilities necessary for a complete energy transition within its own borders, complete autarky is neither feasible nor economically rational (Van de Graaf et al., 2023).

The viable strategic objective is resilient or managed interdependence, a paradigm that acknowledges international trade as essential for cost efficiency and technological diffusion, while asserting that over-reliance on concentrated supply nodes or vulnerable transit chokepoints introduces significant strategic exposure. This addresses the strategic threats posed by maritime vulnerabilities, weaponized trade policies, and wider geopolitical conflicts that fragment global market integration. Trade security thus operates at the intersection of economic statecraft and international logistics, requiring continuous diplomatic and institutional mechanisms to maintain open market access.

This conceptual framework expands upon the foundational energy security literature by adapting classic multidimensional approaches to an era dominated by electrification, critical mineral dependencies, and globalized value chains (Cherp & Jewell, 2014; Sovacool & Mukherjee, 2011). A critical analytical insight is that these three security dimensions do not necessarily move in lockstep; strengthening one dimension can inadvertently weaken another, creating complex strategic trade-offs for policymakers (Jewell et al., 2014; Vivoda, 2010). For instance, a country may enhance its domestic supply security by expanding solar power generation to reduce fossil fuel import dependencies, but if it relies entirely on foreign markets for photovoltaic modules, polysilicon, or processed critical minerals, it creates severe vulnerabilities in its supply-chain security (Helveston & Nahm, 2019). Similarly, a state may diversify its sourcing of raw minerals across multiple global mining suppliers to bolster supply-chain inputs, yet remain exposed to maritime chokepoints or restrictive trade policies, thereby compromising its trade security (Epps & Hughes, 2021; Klinger et al., 2024).

Empirical findings from international energy institutions highlight this structural fragility through disruption modeling for critical minerals such that if the single largest refining or producing country were excluded from the global market, the remaining global capacity would cover only a fraction of projected demand for graphite, RERs (IEA, 2025; Pitron, 2018). This is the result of that global aggregate capacity could obscure acute system vulnerabilities caused by actor concentration and industrial monopolization (Nappi, 2021; Overland, 2019). Furthermore, weaponized trade policies, such as targeted and strict export controls on critical minerals, demonstrate how trade regulation is increasingly utilized as a geopolitical leverage tool in great-power competition (Bradshaw et al., 2023;

Wu, 2023). The strategic restructure for modern states is therefore not isolationist self-sufficiency, but rather the construction of managed interdependence that mitigates concentration risk while retaining the efficiency gains of globalized energy markets (Proskuryakova, 2018).

4. Re-Architecturing of Geoeconomics of Energy

The transformation of the global energy system has fundamentally altered not only the technologies through which energy is produced and consumed, but also the geographical distribution of economic and geopolitical power. In the conventional understanding of energy security, strategic influence was largely associated with the ownership of hydrocarbons, control over transportation corridors, and the ability to protect or disrupt the movement of oil and natural gas. The contemporary energy transition complicates this configuration. Energy security is increasingly determined by the interaction between resource endowments, technological capabilities, industrial capacity, infrastructure, financial power, trade networks and institutional resilience. Consequently, countries and regional blocs occupy increasingly differentiated positions within the global energy system: some remain primarily resource suppliers, some have become indispensable processors or manufacturers, while others derive influence from their capacity to regulate markets, mobilize capital, provide infrastructure or organize international cooperation. Cherp and Jewell (2014) conceptualize energy security as the vulnerability of vital energy systems, emphasizing that vulnerability depends not only on exposure to risks but also on the resilience capacities available to absorb and respond to disruptions. This perspective is particularly relevant to the contemporary energy transition because the sources of vulnerability are becoming increasingly dispersed across international production networks. A country can possess abundant renewable resources and nevertheless remain vulnerable because it depends on imported grid equipment, critical minerals, batteries, semiconductors or specialized technologies. Conversely, a country with limited domestic energy resources may achieve relatively high levels of energy security if it possesses diversified suppliers, flexible infrastructure, strategic reserves, robust institutions and strong technological capabilities. Energy security is therefore increasingly relational rather than purely territorial.

The resulting international landscape is best understood as a system of differentiated strategic positions rather than a simple hierarchy between energy exporters and importers. The European Union illustrates the position of a major energy-consuming and technology-regulating bloc seeking to reduce fossil-fuel dependence while simultaneously managing new dependencies on clean-energy

technologies and critical raw materials. China occupies a different position, combining enormous energy demand with exceptional manufacturing and processing capabilities. The United States combines domestic hydrocarbon abundance with technological, financial, military and institutional power. Russia remains a major hydrocarbon producer, but its strategic position has been transformed by the politicization of energy interdependence with Europe. The Gulf states continue to exercise substantial influence through their control of relatively low-cost hydrocarbon resources while attempting to prepare their economies for a gradually decarbonizing world economy. African countries occupy a particularly complex position because many possess critical mineral resources while simultaneously facing energy poverty, infrastructure deficits and limited industrial capacity. India, meanwhile, represents the developmental energy-security challenge of the Global South, in which rising energy demand, affordability, industrialization and decarbonization must be pursued simultaneously. Türkiye represents yet another distinct configuration, deriving strategic relevance less from resource ownership than from geographical position, infrastructure connectivity and its potential role as an energy and trade hub.

4.1. The European Union: From Import Dependence to Strategic Resilience

The European Union represents perhaps the clearest example of the transformation from conventional energy security towards a multidimensional conception of strategic resilience. For decades, European energy security was strongly influenced by the availability and affordability of imported oil and natural gas, with Russian pipeline gas occupying a particularly important position. Geographic proximity, extensive pipeline infrastructure and relatively competitive prices generated a dense pattern of interdependence between Russia and European consumers. The underlying assumption was that commercial interdependence would create incentives for both sides to maintain stable energy relations.

Russia's full-scale invasion of Ukraine in 2022 fundamentally altered this equilibrium. Energy dependence was reinterpreted as a potential source of strategic vulnerability, and energy policy became increasingly integrated with foreign policy, economic security and industrial policy. The EU's response has involved diversification of suppliers, expansion of LNG infrastructure, greater gas storage, demand reduction, accelerated renewable deployment and increased energy efficiency. REPowerEU represents the institutional expression of this transformation (European Commission, 2025). Yet the academic literature

cautions that diversification should not be equated with the elimination of vulnerability such that Ah-Voun, Chyong, and Li (2024), for instance, show that REPowerEU can substantially reduce European gas demand and Russian dependence, but that residual exposure to global LNG markets and climatic demand variability can remain significant. Similarly, Lambert et al. (2022) demonstrate that replacing Russian gas requires not simply new suppliers but new infrastructure, contractual arrangements and market structures, with the United States and Qatar becoming increasingly important suppliers to European markets.

This creates an important analytical distinction between dependency reduction and vulnerability reduction. Europe may reduce dependence on individual suppliers without reducing overall vulnerability, as energy security risks can shift from bilateral pipeline dependence to dependence on global LNG infrastructure, logistics and markets.

The same logic increasingly applies to renewable technologies. The replacement of fossil-fuel imports with renewable electricity reduces exposure to international fuel-price volatility and supply disruptions, but it increases the importance of imported technologies, critical minerals, manufacturing capacity, grid infrastructure and energy storage. Jewell et al. (2014) demonstrates that decarbonization can reduce several traditional energy-security risks, particularly those associated with fossil-fuel trade, while simultaneously creating new technological and material dependencies. The EU therefore faces a strategic paradox: decarbonization is itself an instrument of energy security, but the technologies required for decarbonization might generate new external vulnerabilities. The European Union's dependence, moreover, on Chinese clean-energy technologies and critical-material processing has increasingly become a strategic concern.

The European Union is consequently moving towards a conception of energy security that combines diversification with strategic industrial capacity. Energy security is increasingly intertwined with industrial competitiveness, trade policy, technological sovereignty and the resilience of critical supply chains. Marhold (2023) argues that the EU's post-2022 energy strategy represents a broader reconfiguration of the trade–energy-security nexus, in which conventional assumptions about markets, protectionism and regulatory openness are increasingly challenged by geopolitical realities.

The European case therefore suggests that strategic autonomy does not necessarily mean autarky. The EU cannot realistically produce domestically all the minerals, technologies and energy resources required for its transition. Its objective is more accurately described as managed interdependence: maintaining

international trade while reducing excessive concentration at strategically indispensable nodes. In this respect, European energy security is increasingly becoming a question of the architecture of interdependence rather than the elimination of interdependence itself.

4.2. China: Energy Security Through Industrial and Value-Chain Power

China occupies a fundamentally different position in the emerging energy-security architecture. It remains one of the world's largest energy consumers and importers, particularly of oil and natural gas, yet its strategic influence cannot be understood through resource ownership alone. China's distinctive strength lies in its ability to connect resource access with processing, manufacturing, technological development and domestic deployment.

This configuration represents a shift from resource power towards value-chain power. In the conventional hydrocarbon system, strategic influence was concentrated in countries possessing large reserves or controlling transportation routes. In the emerging low-carbon system, influence increasingly accrues to countries that occupy critical processing and manufacturing nodes. The strategic importance of a mineral therefore depends not merely on where it is mined, but on where it is refined, transformed into advanced materials and incorporated into industrial products.

China's position in solar photovoltaics, batteries, electric vehicles and critical-mineral processing illustrates this transformation. Its domestic market provides scale, its manufacturing ecosystems generate learning effects, and its industrial capabilities reinforce one another across sectors. The resulting feedback mechanism creates cumulative advantages: large domestic deployment supports industrial scale; scale reduces production costs; lower costs stimulate exports; exports reinforce market share; and market share generates further technological and organizational learning.

This configuration is strategically important because the energy transition does not eliminate material dependence. Vakulchuk et al. (2020) emphasize that renewable energy technologies possess fundamentally different geopolitical characteristics from fossil fuels, but they also generate new dependencies associated with critical materials, technological capabilities and infrastructure. Scholten et al. (2020) similarly argue that renewable-energy geopolitics is likely to become more horizontal and polycentric, but that the transition will generate new forms of strategic competition.

China's centrality in global energy value chains should not be viewed solely as a source of geopolitical risk, as its scale advantages and manufacturing capabilities have significantly reduced the cost of renewable technologies and accelerated their global diffusion. This creates a fundamental policy dilemma: while excessive reliance on Chinese processing and manufacturing can expose countries to geopolitical and trade-related disruptions, complete decoupling could raise transition costs and slow the deployment of clean-energy technologies. The appropriate objective is therefore not to eliminate interdependence, but to reduce excessive concentration by strengthening substitutability and technological innovation. The Chinese case thus demonstrates that power within an energy value chain does not necessarily translate into energy security, highlighting the inherently reciprocal nature of vulnerability in an interconnected global energy system.

4.3. The United States: From Energy Autonomy to Systemic Energy Power

The United States represents a distinct configuration of energy power, deriving its strategic position from the interaction of abundant domestic resources with technological capabilities, financial depth, military capacity, institutional influence and an extensive network of geopolitical alliances. The shale revolution strengthened its position in global oil and gas markets, while expanding LNG exports provided an additional channel of influence over international energy security. Yet, U.S. energy power extends well beyond hydrocarbons, encompassing advanced energy technologies, nuclear capabilities, batteries, semiconductors, digital infrastructure and financial services. Its ability to mobilize private capital and coordinate energy policy with trade, industrial, defence and foreign policy further enhances its systemic capacity to shape markets. This broader configuration is increasingly reflected in efforts such as the Minerals Security Partnership and wider "friend-shoring" strategies, which seek to reduce exposure to highly concentrated critical-mineral and clean-technology supply chains without abandoning international economic integration.

At the same time, U.S. energy power illustrates the growing convergence of energy, finance and macroeconomic security. The central role of the U.S. dollar and the depth of American financial markets provide significant influence over the financial environment surrounding global energy trade, investment and sanctions. Moreover, substantial domestic oil and gas production does not fully shield the U.S. economy from international price volatility, since energy commodities remain embedded in globally integrated markets. The American case

therefore demonstrates that contemporary energy security depends not only on the capacity to produce and supply energy, but also on the ability to shape markets, financial flows and strategic supply chains, highlighting the transition from traditional resource security toward a broader model of systemic and macroeconomic energy security.

4.4. Russian Federation: From Energy Interdependence to the Politicization of Supply

Russia represents perhaps the clearest example of how energy resources can become instruments of geopolitical power, while also demonstrating the limits of such power. Before 2022, Russia's relationship with Europe was based on a dense network of energy interdependence. Pipeline infrastructure connected Russian producers to European consumers, while European markets provided Russia with a major source of revenue.

The concept of the "energy weapon" has long been debated in the academic literature. Smith Stegen (2011) argues that energy resources can become instruments of political influence only under specific structural conditions and finds that several historical cases of alleged Russian energy coercion did not produce the political concessions often attributed to them. This qualification is important because it demonstrates that resource power is neither automatic nor unlimited. Market structure, alternative suppliers, infrastructure, domestic demand and the costs borne by the supplier all influence the effectiveness of energy coercion.

The post-2022 environment nevertheless demonstrated that energy interdependence can become heavily politicized. LaBelle (2023) argues that Russia's restriction of gas flows to Europe represented a contemporary form of energy weaponization, while the EU subsequently responded by using the market and regulatory instruments available to it as instruments of geopolitical strategy. More recent modeling by Hartvig et al. (2024) suggests that the economic consequences of the Russian energy weapon were significant but also accelerated European diversification and renewable deployment.

Russia's energy power has undergone a structural transformation as the European market that historically amplified the geopolitical value of its vast hydrocarbon resources has become increasingly constrained. The strategic significance of Russia's energy position therefore depends not simply on resource abundance, but on its ability to redirect exports toward alternative markets while sustaining the infrastructure, investment and technological capabilities required to do so. The

Russian case illustrates a broader principle of relational energy power: the geopolitical leverage of a resource is determined by the interaction between supplier capabilities, market access and the availability of credible alternatives for consumers. As infrastructure, technology, markets and political relationships evolve, so too does the strategic value of the same physical resource.

4.5. The Gulf States: Managing the Transition Without Abandoning Hydrocarbon Power

The Gulf Cooperation Council states occupy a distinctive position because they combine some of the world's most strategically important hydrocarbon resources with increasingly ambitious plans for economic diversification and renewable-energy deployment. Saudi Arabia, the United Arab Emirates, Qatar and other Gulf states are therefore not simply potential "losers" from the energy transition. They are attempting to shape the transition while preserving the economic and geopolitical value of their existing resource endowments. The strategic challenge is fundamentally intertemporal. Hydrocarbon revenues remain essential to fiscal stability and economic development, yet long-term decarbonization creates uncertainty about future demand for oil and gas. Gulf governments consequently face an incentive to monetize hydrocarbon resources while they retain significant global demand and simultaneously invest revenues in alternative economic sectors.

The literature suggests that this transition is unlikely to be a simple substitution of fossil fuels by renewables. Hanieh (2025) argues that renewable energy in the Gulf is being developed in ways that can coexist with, and in some cases reinforce, hydrocarbon production and export strategies. Similarly, research on the UAE and Saudi Arabia demonstrates that the two countries are pursuing different pathways: the UAE places greater emphasis on diversification and integration into global clean-energy finance networks, whereas Saudi Arabia combines renewable deployment with large-scale industrial localization and continued participation in oil-market management through OPEC+.

This creates a distinctive conception of energy security. For the Gulf, energy security is not simply about securing domestic energy supply. It increasingly involves maintaining export security, fiscal resilience and relevance within the future energy system. Investments in solar power, hydrogen, petrochemicals, carbon-management technologies and critical minerals can therefore be interpreted partly as attempts to preserve strategic relevance beyond the peak of conventional hydrocarbon demand. For these reasons, the Gulf states also

illustrate the importance of export diversification. Whereas import-dependent economies seek to reduce exposure to external suppliers, hydrocarbon exporters must manage the opposite risk: excessive dependence on a narrow set of export commodities and markets. Their energy-security challenge is therefore closely connected to macroeconomic diversification.

4.6. Africa: Energy Security as a Developmental and Industrial Question

Africa occupies perhaps the most structurally asymmetric position in the emerging energy system. The continent possesses substantial deposits of cobalt, copper, lithium, graphite, manganese and other minerals required for electrification and clean-energy technologies. At the same time, many African economies face limited electricity access, inadequate grid infrastructure, high financing costs and weak domestic processing capabilities.

This means that energy security in Africa cannot be reduced to the security of supply. For many African countries, the central problem is the lack of reliable and affordable energy itself. Energy availability is a prerequisite for industrialization, manufacturing, digitization and value addition. Energy security therefore becomes inseparable from development policy.

This creates a striking paradox. The countries possessing resources that are strategically valuable for the global energy transition may themselves face insufficient energy systems to process those resources domestically. Mineral security and energy security therefore become mutually reinforcing. Without affordable electricity, mineral-rich economies may remain confined to extraction and export, capturing only a limited share of the value generated by global clean-energy industries.

Recent research supports this developmental interpretation. Ongo Nkoa and Fonguen-Kong-Ngoh (2024), using panel evidence from 25 African countries, find that energy consumption has an important relationship with industrial value added and argue for international financing mechanisms capable of supporting energy transition and green industrialization. Kilinc Ata and Proskuryakova (2025) similarly show that renewable-energy expansion is associated with mineral trade dynamics in resource-rich African economies and emphasize the need for resilient and inclusive mineral strategies.

The central question for Africa is therefore whether the energy transition will reproduce the historical pattern of commodity dependence or create opportunities

for industrial upgrading. This outcome is not predetermined. It will depend on bargaining power, infrastructure, electricity availability, domestic industrial policy, investment conditions, regional integration and the ability of African governments to negotiate value-adding arrangements with international investors.

The geopolitical dimension of this challenge is becoming increasingly important. The EU, United States and China all have strategic interests in African critical minerals, creating new opportunities for African producer countries but also the possibility of reproducing asymmetric relationships. Boafo et al. (2025) argue that European energy-transition diplomacy towards Africa may simultaneously create opportunities for development and reinforce Africa's position as a supplier of raw materials unless domestic value addition is explicitly incorporated into cooperation frameworks.

The African case therefore reveals that the energy transition is not automatically developmental. Renewable technologies may be low-carbon at the point of use while their upstream value chains reproduce unequal patterns of value capture. Energy security, industrial policy and development strategy must consequently be analyzed together.

4.7. India and the Emerging Global South: Energy Security Under Developmental Constraints

India represents another distinctive configuration. As a rapidly growing major economy, it must simultaneously address rising energy demand, energy affordability, industrialization, energy access and decarbonization. Unlike advanced economies that can frame the energy transition primarily around replacing established fossil-fuel systems, India must expand energy consumption while transforming its composition. This produces a dual energy-security strategy. In the short and medium term, India seeks to diversify its external fossil-fuel suppliers and strengthen strategic partnerships with resource-rich countries. In parallel, it is expanding renewable energy, energy efficiency and domestic technological capabilities. Recent research characterizes this as a combination of external diversification and domestic green transition. India is particularly important because it highlights the limitations of applying advanced-economy conceptions of energy security to the Global South, where energy security is not limited to resilience against price and supply shocks but also entails securing sufficient and affordable energy to sustain economic transformation and expand access. This distinction is central to global climate governance, as an energy transition that raises costs for developing economies without adequate access to

finance, technology and infrastructure may deepen the tension between climate and development objectives, whereas affordable renewable technologies and financing can enable these economies to expand energy access while avoiding long-term fossil-fuel lock-in. India therefore also demonstrates the growing strategic agency of the Global South, whose future role will extend beyond adapting to policies designed elsewhere to actively shaping the standards, technologies, financing mechanisms and trade rules that will govern the emerging global energy system.

4.8. International Organizations and Regional Institutions: From Coordination to Governance

The emerging architecture of energy security cannot be explained solely through the behaviour of individual countries. International and regional institutions increasingly influence how risks are identified, how markets are regulated and how collective responses are coordinated. The European Union represents the strongest example because energy policy is partly supranational, but institutions such as the International Energy Agency (IEA), International Renewable Energy Agency (IRENA), World Trade Organization (WTO), OPEC and multilateral development banks also influence the structure of global energy relations.

The role of such institutions is becoming more complex because the boundaries between energy policy, trade policy, industrial policy and national security are increasingly blurred. Critical minerals, for example, simultaneously concern resource access, industrial competitiveness, environmental regulation, trade restrictions and national security. Similarly, renewable-energy technologies involve investment policy, intellectual property, supply-chain resilience and trade rules.

International institutions therefore face a fundamental coordination dilemma: measures intended to strengthen national energy resilience may simultaneously deepen global fragmentation, as export restrictions can improve domestic supply security while constraining international availability, local-content requirements can support domestic industries while increasing costs, strategic subsidies can accelerate technological deployment while intensifying competition, and investment screening can mitigate security risks while limiting cross-border capital flows. The central challenge is thus to reconcile strategic resilience with the efficiency gains of international specialization, particularly as the energy transition requires unprecedented levels of cross-border investment, technology transfer and trade. Rather than pursuing complete self-sufficiency, the emerging

global energy order requires institutions capable of managing interdependence, reducing excessive vulnerabilities and preserving the benefits of international cooperation under conditions of geopolitical competition.

5. Türkiye: From Energy Corridor to Regional Energy and Trade Hub

Türkiye occupies a distinctive position in the emerging architecture of global energy security. Unlike major energy powers whose geopolitical influence derives primarily from abundant hydrocarbon reserves, Türkiye's strategic significance rests on the interaction of geography, infrastructure, market size, industrial capacity, diplomatic connectivity and proximity to both energy-producing and energy-consuming regions. Situated at the intersection of Europe, the Black Sea, the Caucasus, Central Asia, the Middle East and the Eastern Mediterranean, Türkiye is positioned between several major resource geographies and one of the world's largest energy markets, Europe. This geographical centrality has historically enabled the country to function as an important transit route for oil and natural gas, while more recently it has encouraged ambitions to transform Türkiye from an energy corridor into a regional energy hub. The literature nevertheless suggests that geography alone does not generate geopolitical power. Rather, geographical centrality becomes strategically valuable when it is supported by infrastructure, diversified supply and demand, functioning markets, institutional capacity and the ability to generate economic value from energy flows (Austvik & Rzayeva, 2017; Erşen & Çelikpala, 2019).

This distinction is particularly important for understanding Türkiye's contemporary energy-security position. In conventional terms, Türkiye remains structurally vulnerable because its domestic energy demand substantially exceeds its indigenous production of fossil fuels. Consequently, energy security cannot be understood merely as the physical availability of energy but must also be considered in relation to import dependence, price volatility, external balances and the resilience of infrastructure and supply chains. Recent research continues to identify the country's high dependence on imported fossil fuels as a major source of macroeconomic vulnerability, while simultaneously emphasizing the growing strategic role of renewable energy in reducing this exposure (Demir, 2025). Türkiye's energy-security challenge is therefore inherently dual: it must secure sufficient and affordable energy for a large and industrializing economy while reducing the macroeconomic and geopolitical risks associated with external dependence. In this respect, the broader conception of energy security proposed

by Cherp and Jewell (2014), which moves beyond narrow supply disruption concerns toward the resilience of energy systems under changing technological, economic and geopolitical conditions, provides a particularly useful analytical framework.

Türkiye's geographical position has traditionally been the principal source of its energy-geopolitical significance. Major oil and natural-gas infrastructure has connected the country with Russia, Azerbaijan, the Caspian region, Iraq and the broader Middle East, while its proximity to European markets has increased its value as a potential bridge between producers and consumers. The Southern Gas Corridor and TurkStream have reinforced this position, although they represent different geopolitical relationships and different forms of dependence. Erşen and Çelikpala (2019) demonstrate that Türkiye's geographical location is simultaneously an advantage and a constraint: the same geopolitical environment that creates opportunities for energy transit also exposes Ankara to conflicts and rivalries among Russia, the European Union, the Caucasus, the Middle East and the Eastern Mediterranean. Thus, Türkiye's energy geography should not be interpreted as an automatic source of geopolitical leverage. Its value depends on Türkiye's ability to balance competing suppliers, consumers and political actors without allowing its energy infrastructure to become excessively dependent on a single geopolitical relationship.

The distinction between an energy corridor and an energy hub is therefore central to Türkiye's geoeconomic trajectory. A corridor primarily provides transportation capacity between producers and consumers, whereas a hub requires a more sophisticated market ecosystem in which multiple sources can be aggregated, stored, traded, priced and redistributed. Austvik and Rzayeva (2017) emphasise that Türkiye's potential to become a natural-gas hub depends not simply on its location but also on domestic demand, market regulation, infrastructure and the economic viability of alternative supply routes. Similarly, Novikau and Muhasilović (2023) argue that Türkiye's energy-hub strategy seeks to transform the country from a territory through which energy passes into a market in which international buyers and sellers can interact. The distinction has become even more important after the Russian invasion of Ukraine, as Europe's effort to reduce its dependence on Russian energy has increased the strategic value of alternative suppliers, routes and infrastructure. Türkiye's LNG facilities, pipeline network, storage capabilities and connections to the Southern Gas Corridor provide an important foundation for such diversification. Yet a genuine hub requires more than physical infrastructure: market liquidity, transparent pricing, regulatory predictability and diversified sources of supply are equally important.

From this perspective, Türkiye's energy security can be conceptualized through three mutually reinforcing dimensions: supply security, supply-chain security and trade security. Supply security concerns the diversification of energy sources and the reduction of excessive exposure to individual suppliers. Supply-chain security concerns the resilience of pipelines, LNG facilities, storage, electricity grids, generation assets and increasingly digital energy infrastructure. Trade security, meanwhile, concerns Türkiye's capacity not merely to receive energy but to participate in its commercial organization through storage, trading, pricing and redistribution. The latter dimension is particularly important because it creates the possibility of transforming energy security from a defensive policy objective into a source of economic and geopolitical power.

The changing structure of European energy security strengthens the relevance of this ambition. The post-2022 European energy environment has accelerated diversification away from Russian hydrocarbons and increased the importance of alternative suppliers and infrastructure. For Türkiye, this creates opportunities but also a more competitive environment. Its strategic value is not derived from being the sole alternative to Russia; rather, it lies in its capacity to connect several energy-producing regions with European markets while maintaining access to multiple supply options. This is consistent with the concept of resilient interdependence developed in the broader energy-security literature: the objective is not to eliminate interdependence, which is economically unrealistic, but to diversify it and make it more manageable. Türkiye is therefore potentially valuable to Europe not simply as an energy supplier but as an intermediary node within a diversified regional energy system.

At the same time, Türkiye's energy security is increasingly being reshaped by the transition from hydrocarbons toward renewable and low-carbon energy. This transformation creates a paradox. Renewable energy reduces dependence on imported fuels and therefore has the potential to strengthen energy security, but it can simultaneously create new dependencies on imported technologies, critical minerals, components and technological know-how. Recent research on Türkiye's energy transition highlights precisely this duality: the country possesses substantial solar and wind potential, but the effective mobilization of these resources requires investment in transmission infrastructure, storage, grid flexibility and technological capabilities (Gulaydin & Mourshed, 2025). Consequently, Türkiye's energy transition should not be conceptualized simply as a shift from imported fossil fuels to domestic renewable electricity. It represents a broader restructuring of the country's external dependencies.

This is where energy policy increasingly converges with industrial and trade policy. The energy transition creates demand for solar panels, wind turbines, batteries, power electronics, grid equipment, electric vehicles, hydrogen technologies and critical minerals. Countries that possess renewable resources but lack industrial capabilities may reduce their dependence on fossil fuels while becoming dependent on foreign technologies and upstream value chains. Türkiye's relatively diversified manufacturing base therefore constitutes an important strategic asset. Its proximity to European markets, participation in European manufacturing networks and position between resource-rich regions create opportunities to integrate energy transition with industrial upgrading. The objective should consequently be strategic participation in emerging energy value chains rather than technological autarky.

The macroeconomic dimension makes this transformation particularly important for Türkiye. Energy imports have historically constituted an important source of pressure on the country's external balance, making global oil and gas price fluctuations relevant not only to energy policy but also to inflation, the current account, exchange-rate pressures and overall macroeconomic stability. In this context, renewable-energy investment can generate benefits extending beyond emissions reduction. Gözkün and Orhangazi (2025), using input-output analysis, estimate that a major solar and wind investment program could generate additional economic growth, substantial employment effects and significant improvements in Türkiye's trade balance over a ten-year period. Their findings indicate that renewable investment could contribute an additional 0.6–1.8% to annual GDP, create employment equivalent to 1.3–3.4% of the 2020 labor force and improve the trade balance by approximately US$6.9–14.6 billion over ten years. These results reinforce the argument that energy transition should be treated not simply as an environmental policy but as an element of macroeconomic resilience and industrial strategy.

Recent empirical evidence also suggests that renewable energy can affect Türkiye's broader external economic performance. Demir (2025) finds evidence that an increasing share of renewable energy in total energy production is associated with higher exports, lower imports, lower inflation and stronger per-capita income growth. While such relationships should not be interpreted as implying that renewable energy automatically eliminates external vulnerability, they support a broader understanding of energy security in which domestic energy production contributes simultaneously to economic resilience and external-balance stability. Türkiye's renewable-energy expansion can therefore be understood as a form of macroeconomic risk diversification: it reduces the

exposure of domestic production to internationally determined fossil-fuel prices while increasing the share of domestically generated energy in the economy.

The development of domestic natural-gas production in the Black Sea adds another layer to this diversification process. Domestic gas production cannot eliminate Türkiye's structural dependence on imported energy, but it can increase supply flexibility and reduce the extent to which international shocks are transmitted directly into the domestic economy. Similarly, nuclear power introduces another element into Türkiye's emerging energy portfolio. Rather than viewing nuclear, natural gas and renewable energy as mutually exclusive alternatives, Türkiye's energy-security challenge could be interpreted as one of portfolio construction, in which reliability, affordability, sustainability and geopolitical resilience must be balanced simultaneously. The central policy question is therefore not which single energy source should dominate, but how different energy sources and technologies can collectively reduce systemic vulnerability.

Türkiye's geoeconomic position is also increasingly shaped by the Eastern Mediterranean. Hydrocarbon discoveries in the region have transformed the Eastern Mediterranean into a space where energy markets, maritime jurisdiction, diplomacy and regional security intersect. Goldthau et al. (2024) indicates that the region's energy resources have not simply generated commercial opportunities; they have also contributed to new patterns of regionalization involving states, international energy companies, investors and regulators. For Türkiye, the Eastern Mediterranean therefore represents both an energy-security challenge and a potential source of strategic connectivity. Its policy toward the region has been strongly influenced by concerns over maritime jurisdiction, access to energy resources and the possibility of being excluded from emerging regional energy architectures. At the same time, recent research suggests that the post-2022 environment has created incentives for a gradual reassessment of highly securitized energy relationships and greater emphasis on diplomatic engagement and regional normalization (Fırat & Dağ, 2023).

The Eastern Mediterranean dimension reinforces the importance of Türkiye's broader diplomatic flexibility. Türkiye's energy relationships extend simultaneously toward Europe, Russia, Azerbaijan, Central Asia, the Middle East and the Eastern Mediterranean. In an increasingly fragmented international system, this diversified diplomatic geography can constitute an important geoeconomic asset. The country does not necessarily benefit from permanently aligning its energy strategy with a single geopolitical bloc. Its comparative advantage may instead derive from maintaining sufficient connectivity across

different political and economic systems. Such an approach corresponds to the broader transformation of energy geopolitics from rigid bloc competition toward selective de-risking, diversified interdependence and competing networks of infrastructure and value chains.

The next stage of Türkiye's energy-geoeconomic strategy should therefore extend beyond hydrocarbons. The transition toward electricity-based energy systems increases the importance of electricity interconnections, renewable-energy technologies, storage, hydrogen and its derivatives, critical minerals, advanced materials and digital infrastructure. Türkiye's geographical position between Europe and resource-rich regions creates potential opportunities in these emerging value chains. Its role could consequently evolve from that of an energy bridge into a broader regional platform connecting resources, technologies, industrial production and consumer markets. The strategic significance of this transformation lies in the possibility of capturing value domestically rather than merely collecting transit revenues.

This dual orientation suggests that Türkiye's energy diplomacy can no longer be understood solely through the traditional lens of fossil-fuel supply security and transit geopolitics. Rather, energy security and climate diplomacy are increasingly converging into a broader geoeconomic strategy. Duman (2026) conceptualizes this development as a dual-track approach in which Türkiye simultaneously seeks closer alignment with the European Green Deal to safeguard trade competitiveness and access to green finance, while maintaining regional partnerships that support access to energy resources and critical raw materials. Such an approach allows Türkiye to occupy an intermediate but potentially influential position between decarbonization and energy sovereignty. Its strategic value therefore lies not merely in transporting energy between producing and consuming regions, but increasingly in connecting energy security, climate policy, trade, industrial transformation and emerging clean-technology value chains.

Critical minerals illustrate this transformation particularly clearly. The global energy transition is increasing demand for minerals and materials required for batteries, renewable-energy technologies, electrification and digital infrastructure. Türkiye's geoeconomic opportunity should therefore not be restricted to securing access to mineral resources. A more ambitious strategy would connect exploration and extraction with processing, recycling, advanced materials, manufacturing and logistics. Such an approach would allow Türkiye to participate in multiple stages of emerging energy value chains and thereby reduce the risk that the country merely replaces fossil-fuel dependence with technological dependence. In this respect, Türkiye's industrial base and proximity to European markets provide an

important foundation for a strategy centered on value-chain participation rather than resource ownership alone (IEA, 2025e; IEA, 2025f).

The central challenge, however, is converting connectivity into durable market power. Türkiye's geographical centrality is a necessary but insufficient condition for energy-hub status. Infrastructure must be supported by competitive markets, transparent regulation, diversified suppliers, sufficient storage, balancing mechanisms, market liquidity and confidence among international investors and trading partners. This point is particularly important because energy infrastructure can generate geopolitical influence without necessarily producing durable geoeconomic power. Unless infrastructure is embedded in commercially viable markets and diversified economic relationships, transit capacity may remain vulnerable to changes in supplier strategies, demand conditions or geopolitical tensions. Austvik and Rzayeva (2017) and Erşen and Çelikpala (2019) both underline the importance of the interaction between infrastructure, market conditions and geopolitical developments in determining Türkiye's ability to realize its energy-hub ambitions.

Türkiye's contemporary position can therefore be characterized as a transition from an energy corridor toward a regional energy and trade platform. Its strategic power increasingly derives from the ability to connect rather than simply to produce. This connectivity encompasses not only pipelines and LNG terminals but also electricity grids, renewable-energy investments, industrial supply chains, critical-mineral networks, logistics infrastructure and European manufacturing markets. The emerging configuration of global energy security makes such network positions increasingly valuable because energy power is progressively determined by control over connections between resources, technologies, production systems and markets.

The strategic objective for Türkiye should consequently be to transform energy security from a defensive policy concerned primarily with avoiding shortages into a productive geoeconomic strategy that contributes to macroeconomic stability, industrial upgrading, technological capability and regional influence. This requires systemic diversification of suppliers and routes, accelerated deployment of domestic renewable resources, investment in storage and grid flexibility, development of energy-trading capabilities, integration of critical minerals into industrial policy, and an energy diplomacy increasingly oriented toward technology, electricity, hydrogen and clean-energy value chains. The underlying objective should not be autarky but resilient interdependence.

In this sense, Türkiye's most significant energy-geoeconomic opportunity lies in moving progressively from corridor to platform. Such a transformation would

mean moving from transporting energy to facilitating energy trade; from relying on imported technologies to developing selected domestic technological capabilities; from importing strategic materials to participating in their processing and value addition; and from being a geographical bridge between external actors to becoming an active node within regional and global energy networks. Türkiye's energy security and geopolitical influence will ultimately depend not on whether it possesses the largest energy reserves, but on whether it can convert its geographical centrality, infrastructure, industrial capabilities and diplomatic connectivity into durable economic value and strategic autonomy.

6. Conclusion

Energy security is no longer determined by what countries possess, but by what they are capable of securing, transforming, connecting and sustaining within an increasingly fragmented global energy system. The concrete change in the structure of the global energy system is not simply a transition from one set of fuels to another; it is a fundamental reorganization of the economic, technological and geopolitical foundations upon which modern economies depend. Throughout much of the twentieth century, energy security was primarily understood in terms of securing continuous and affordable supplies of oil, natural gas and electricity, protecting transportation routes and reducing exposure to geographically concentrated fossil-fuel resources. The modern energy system, however, has fundamentally altered the location and nature of these vulnerabilities. Decarbonization, electrification, digitalization, technological change and the fragmentation of globalization have shifted strategic attention from individual commodities toward the networks, technologies, infrastructures and value chains through which energy is produced, transformed, transported, traded and consumed. The central implication is therefore that energy security can no longer be adequately understood as a commodity-specific condition. It is increasingly a systemic capability: the capacity of an economy to access energy, transform resources into usable forms, transport and trade them, absorb external shocks and adapt to technological and geopolitical change. This broader understanding is consistent with the multidimensional treatment of energy security in the literature and with empirical evidence showing that energy-security shocks can have significant effects on economic growth, particularly when geopolitical tensions amplify energy-price and transportation risks (Alam et al., 2025).

This systemic perspective establishes a direct link between energy security and macroeconomic resilience, as energy prices, availability and reliability shape inflation, production costs, investment, trade balances and international

competitiveness, allowing disruptions to propagate from sectoral disturbances into broader macroeconomic shocks. Cross-country evidence confirms that energy-security shocks negatively affect short-run economic growth, with these effects becoming more pronounced under heightened geopolitical tensions (Alam et al., 2025), while oil-price volatility can similarly constrain output growth, although financial institutions may moderate some of these effects (Kang et al., 2019). At the same time, the energy transition does not eliminate these vulnerabilities but redistributes them across new geographical and economic nodes: declining dependence on concentrated fossil-fuel resources is accompanied by greater reliance on critical minerals, processing and refining capacity, manufacturing, technological capabilities, electricity grids, storage and specialized infrastructure. As Hache (2018) cautioned, renewable energy can generate new dependencies on critical materials and technological assets, while Vakulchuk et al. (2020) show that renewables bring both important security benefits and emerging geopolitical risks, including those related to critical materials and cybersecurity. Energy security should therefore be integrated into broader macroeconomic and economic-security strategies and understood not as a transition from dependence to independence, but as a transformation from one configuration of interdependence to another.

This is the conceptual foundation of Energy Security 2.0 developed in this chapter. Its strategic unit is no longer simply the barrel of oil, cubic meter of gas or kilowatt-hour considered in isolation, but the network connecting energy resources, critical minerals, processing, technology, infrastructure, electricity, trade, finance and data. The critical question is consequently not merely who possesses a resource, but who controls the strategically important nodes through which that resource becomes economically and technologically valuable. A country may possess substantial mineral reserves without possessing refining capacity; another may dominate advanced manufacturing while depending on imported minerals or components; a third may possess abundant renewable resources while remaining vulnerable because it relies on imported grid equipment, storage technologies or specialized machinery. Critical-mineral supply chains illustrate this transformation particularly clearly. The strategic vulnerability of these chains is increasingly concentrated downstream, where refining and processing can be more concentrated and persistent than mining itself (Chepeliev et al., 2026). The competition surrounding critical minerals is reflected in the emerging competition between resource-producing economies and downstream processing powers, particularly China (van der Ploeg & Venables, 2026).

These also fundamentally reshape the geoeconomics of energy. Power in the emerging energy system derives increasingly from the ability to control or connect markets, infrastructure, technology, investment, logistics, finance and supply chains. As Quitzow and Zabanova (2025) emphasize, this transformation can be understood through the interaction of resources, technology and data; markets and networks; and the rules governing international economic relations. Strategic autonomy therefore does not imply autarky. Complete self-sufficiency is neither realistic nor necessarily desirable in an interconnected global economy characterized by geographically uneven resources, specialized technologies and internationally mobile capital. International trade and cross-border investment remain indispensable to the energy transition, while participation in global value chains can influence several dimensions of energy security (Ha & To, 2022). The appropriate objective is consequently resilient interdependence: maintaining the benefits of international specialization while reducing the risk that excessive concentration at critical nodes can turn interdependence into systemic vulnerability.

This principle has important implications for diversification and policy design. Diversification should not be reduced to simply increasing the number of suppliers of a particular commodity. It should seek to ensure that disruption at one node does not disable the wider system. This requires alternative suppliers and transportation routes, strategic inventories, recycling and substitution, flexible infrastructure, domestic and regional processing capacity, resilient electricity systems and mechanisms for international cooperation. It also requires distinguishing among three mutually reinforcing dimensions of security: supply security, concerning the physical availability of energy; supply-chain security, concerning the systems that transform resources into usable energy and technologies; and trade security, concerning the ability of energy, technologies and intermediate goods to move across borders predictably and at acceptable cost. A country may have abundant resources but weak infrastructure, substantial mineral reserves but limited refining capacity, or advanced manufacturing capabilities but vulnerable trade routes. Energy security is therefore increasingly a property of the network as a whole rather than a simple reflection of domestic resource endowments.

We could also extend our implications directly into industrial and trade policy. Subsidies, local-content requirements, investment screening, export restrictions and strategic stockpiling may strengthen national resilience, but they can also increase costs and fragment international markets. The central policy challenge is therefore not to eliminate global value chains, but to prevent excessive concentration within strategically indispensable nodes. This challenge is

particularly acute for developing economies, where resource abundance does not automatically translate into development. Without processing, technological upgrading, infrastructure investment and industrial diversification, the emerging mineral economy could reproduce elements of the traditional resource-dependent development model. The distribution of gains from the energy transition will consequently depend not only on who possesses critical resources, but also on who can capture higher-value segments of the associated value chains (Arezki et al., 2026). This makes industrial upgrading, technological capability and value addition central components of energy security rather than secondary economic objectives.

The comparative analysis in this chapter demonstrates that energy power is increasingly shaped by position within global value chains rather than by resource ownership alone. Europe shows how reducing one dependency can create new vulnerabilities, making energy security inseparable from industrial and trade strategy; China highlights the geoeconomic power generated by processing, manufacturing and technological capabilities; the United States illustrates the strategic value of combining domestic resources with technology, finance and industrial capacity; while Africa and India underscore the developmental dimension of energy security, where value addition, affordable energy and access to technology are essential for inclusive transformation. Taken together, these cases suggest that the emerging energy order will not simply shift power from petrostates to mineral states, but redistribute it across interconnected centers of extraction, processing, manufacturing, technology, finance, infrastructure and markets.

Within this changing geography, Türkiye's strategic position derives less from fossil-fuel ownership than from connectivity. Its geographical location between major energy-producing and energy-consuming regions, transportation infrastructure, industrial base and access to multiple regional markets provide the foundations for a potential transition from an energy-transit country toward a regional energy geoeconomic power. Yet such a transition cannot be achieved through pipelines alone. It requires deeper and more liquid energy markets, storage, diversified supply, electricity interconnection, renewable generation, flexible infrastructure, technological capabilities and integration with regional industrial and trade networks. Türkiye's strategic advantage therefore lies in its ability to extend connectivity beyond hydrocarbons toward electricity, renewable energy, green technologies, critical minerals, logistics and industrial value chains. In this sense, the country's future energy strategy should be embedded within a broader energy–trade–industry–technology nexus, where connectivity becomes not merely a geographical advantage but an economic capability.

At the global level, this transformation ultimately changes the fundamental question of energy geopolitics. The central question is no longer simply "Where will energy come from?" but increasingly "Who will control the systems that make the new energy economy possible?" The answer will shape not only energy security, but also industrial competitiveness, trade, investment, technological leadership and macroeconomic stability. Energy security is therefore becoming inseparable from economic security. The defining strategic objective is not to eliminate dependence, which is neither possible nor necessarily desirable, but to prevent dependence from becoming vulnerability. This requires diversification without fragmentation, strategic autonomy without autarky, industrial policy without excessive protectionism, technological development without exclusionary competition, and decarbonization without reproducing asymmetric patterns of resource dependence.

The deepest implication of Energy Security 2.0 is consequently that power in the new energy order will increasingly belong to those capable of connecting and coordinating networks rather than merely possessing resources. Mineral networks, manufacturing networks, electricity grids, technological ecosystems, financial systems and trade routes are becoming the foundations of strategic influence. The energy transition is therefore neither the end of energy geopolitics nor a simple replacement of fossil-fuel geopolitics with mineral geopolitics. It is a transformation in the architecture of global interdependence. Renewable energy may reduce some vulnerabilities while creating others; electrification may reduce hydrocarbon dependence while increasing dependence on minerals, grids and technologies; diversification may enhance resilience while increasing costs; and strategic autonomy may strengthen security while fragmenting markets. The future energy order will be determined by how states, firms and institutions manage these trade-offs.

Ultimately, the most resilient economies will not necessarily be those with the largest energy reserves, nor those seeking complete self-sufficiency. They will be those capable of constructing diversified, technologically sophisticated and adaptable systems of interdependence. Energy security in the twenty-first century is therefore not about simply having energy; it is about possessing the capacity to access, transform, transport, trade, secure and adapt to energy and the systems that enable it under conditions of uncertainty. In this emerging order, geoeconomic power will accrue to those who can connect resources to markets, technologies to industries, infrastructure to trade, and finance to innovation—and who can keep these connections functioning when geopolitical or economic shocks disrupt them. The future of energy security will therefore be determined not by the

elimination of interdependence, but by the capacity to make interdependence resilient.

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Effect of Liquidity Management on The Financial Performance of Commercial Banks (Case Study: Selected Commercial Banks of Afghanistan From 2014-2020)

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Abstract

This study examines the association between liquidity management and Return on Asset (ROA) in ten Afghan commercial banks during 2014-2020. The balanced panel contains 70 bank-year observations. The empirical model is estimated using Pooled Ordinary Least Squares (OLS), with poolability, random-effects LM, and Hausman tests used to assess the estimator choice. The model is jointly significant ($F = 6.6692$, $p < .001$), with $R^2 = .731337$ and adjusted $R^2 = .621678$. In the baseline estimates, current Revenue Growth (RG) is positive and statistically significant (beta = .032211, $p < .001$), whereas RG_LAGGED is negative and statistically significant (beta = -.027078, $p < .001$). The remaining bank-level, ownership, and macroeconomic variables are not significant at the 5% level. Bank-clustered standard errors and winsorized estimates retain the signs of both RG coefficients, but an influential-bank check shows that the RG_LAGGED result is sensitive to Bank-e-Millie Afghan. The findings are, therefore, presented as conditional associations rather than causal effects. The study contributes evidence from an under-researched fragile banking system and provides a transparent account of model selection, diagnostics, and coefficient sensitivity.

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Keywords: Liquidity management; Bank performance; ROA; Afghan banks; LCR; Panel data; Fragile economy.

JEL: G21, G28, C33, G32

1-Introduction

The banking sector plays a critical role in maintaining economic stability and driving growth by facilitating financial intermediation, enabling transactions, and supporting investment activities. Beyond these core functions, liquidity management remains a fundamental determinant of financial health, ensuring that banks can meet their short-term obligations while maintaining profitability. The 2007-2008 global financial crisis illustrated the consequences of inadequate liquidity and risk management (Santomero, 1997). In response, the Basel Committee strengthened its principles for liquidity-risk supervision and later introduced the Liquidity Coverage Ratio (LCR) and Net Stable Funding Ratio (NSFR) standards (Basel Committee on Banking Supervision, 2008, 2013, 2014).

Effective liquidity management is even more critical in fragile and developing economies like Afghanistan, where the financial sector operates within a volatile political and economic environment. Between 2014 and 2020, the withdrawal of international forces, the reduction of foreign aid, and the overall economic downturn created serious liquidity pressures in Afghan banks (World Bank, 2020). The International Monetary Fund (2019) noted that these conditions led to a decline in deposits, an increase in non-performing loans, and restricted lending capacity. Consequently, Afghan banks faced the challenge of maintaining adequate liquidity while striving for profitability under considerable uncertainty.

This study investigates the relationship between liquidity management and the financial performance of Afghan commercial banks. The bank-level indicators are the Liquidity Coverage Ratio (LCR), Cash Ratio (CASH_RATIO), Operating Cash Flow Ratio (OCFR), Net Working Capital to Total Assets (NWC/TA), Trend Cash Deposits (TCD), Leverage (L), Revenue Growth (RG), and Capital Intensity (CI). Return on Asset (ROA) is the dependent variable. The panel covers 10 commercial banks from 2014 to 2020.

Existing evidence is mixed and varies with the liquidity measure, country income level, institutional conditions, and estimator. Global studies report positive, negative, and nonlinear relationships, while studies of developing and transition economies show that the same bank-level driver can change sign across settings (Bordeleau & Graham, 2010; Dietrich & Wanzenried, 2014; Djalilov & Piesse,

2016; Duan & Niu, 2020). Direct bank-level evidence for Afghanistan remains limited.

The study makes three practical contributions. First, it supplies bank-level evidence from a fragile economy that is seldom represented in cross-country studies. Second, it jointly evaluates several liquidity measures, ownership, macroeconomic controls, current bank-level variables, and their corresponding _LAGGED terms within a unified empirical specification. Third, it reports model-selection, panel diagnostic, clustered-inference, winsorization, and influence checks. The contribution is, therefore, empirical and contextual; it does not claim to identify a causal or universally optimal level of liquidity.

2-Literature Review

2.1 Theoretical Background

The relationship between liquidity and profitability begins with a familiar trade-off. Keynes' Liquidity Preference Theory (1936) explains why liquid resources are held for transaction, precautionary, and speculative purposes. For banks, liquidity supports withdrawals and payment obligations, but highly liquid assets may earn less than longer-term loans or investments. The LCR formalizes part of this trade-off by requiring sufficient high-quality liquid assets to withstand a 30-day stress period (Basel Committee on Banking Supervision, 2013).

Banking theory also stresses that liquidity creation is central to financial intermediation. Diamond and Rajan (2001) explain how fragile short-term funding can support the transformation of illiquid loans into liquid claims, while Berger and Bouwman (2009) develop broad measures of liquidity creation across bank activities. Shiftability and liability-management approaches add that banks may respond to liquidity needs through marketable assets or funding adjustments (Bhattacharya, 2011). These mechanisms are more constrained when interbank and secondary markets are shallow.

2.2 Global Evidence

Large-sample evidence shows that profitability is shaped by bank characteristics, macroeconomic conditions, and the wider financial structure. Demirgüç-Kunt and Huizinga (1999), using banks from 80 countries, find that profitability differences reflect both bank-level and institutional factors. Athanasoglou, Brissimis, and Delis (2008) similarly show that bank-specific, industry-specific, and

macroeconomic determinants matter for Greek banks. These studies provide a broad framework, but they do not imply that one liquidity proxy will have the same coefficient in every banking system.

Studies focused more directly on liquidity also reject a single universal effect. Bordeleau and Graham (2010) find that liquid-asset holdings can support profitability up to a point but become costly beyond it. Duan and Niu (2020) find a positive association between liquidity creation and profitability for U.S. banks. Together, these results show that regulatory liquidity, liquid-asset ratios, liquidity risk, and liquidity creation are related but not interchangeable concepts. A study using LCR and cash-flow ratios should, therefore, interpret each measure separately.

2.3 Evidence from Developing and Transition Economies

Evidence from developing economies is also mixed. Dietrich and Wanzenried (2014), covering banks across low-, middle-, and high-income countries, show that profitability determinants differ substantially across income groups. Al-Harbi (2019) reports that equity, ownership, macroeconomic conditions, and market structure matter in developing and underdeveloped OIC countries. Naceur and Omran (2011) find that regulation, competition, and financial reform shape MENA bank performance, while Djalilov and Piesse (2016) document different profitability drivers across transition countries.

More focused regional studies reinforce the need to distinguish between liquidity measures. Mohammad and Khan (2024) identify a concave liquid-assets-profitability relationship in South Asia. Haris, Yao, and Fatima (2024) report that liquidity risk is positively related to ROA in parts of their Pakistan sample, while credit risk is negative. Yimer (2024) finds different signs for alternative liquidity ratios among Ethiopian microfinance institutions. Although the samples are not identical to Afghan commercial banks, their results show why conclusions should follow the particular coefficient and test rather than a general statement about liquidity management.

2.4 Fragile Economies and the Afghan Context

Fragile economies face additional constraints. Political uncertainty, weak confidence, narrow financial markets, and reliance on external assistance can weaken credit demand and limit the investment opportunities available to banks (International Monetary Fund, 2019; World Bank, 2020). These conditions can

also produce large differences across banks and years, making estimates sensitive to a small number of observations.

The Afghan case is especially relevant. The World Bank (2021) reported that banking-sector liquidity was high at the end of 2020 partly because lending was very limited and substantial funds were held as excess reserves or central-bank instruments. In that setting, a high liquidity ratio may reflect caution and weak loan demand rather than an active strategy that directly raises or lowers profitability. Shallow interbank markets may also make it harder for banks to substitute market funding for balance-sheet liquidity.

These institutional features offer plausible reasons why Afghan coefficients may differ from results obtained in large, diversified, or more stable banking systems. They also require caution: The present annual panel can identify conditional correlations, but it cannot isolate depositor confidence, credit demand, regulatory enforcement, or political risk as separate causal channels.

2.5 Research Gap and Contribution

Despite a substantial international literature, little published bank-level work examines several liquidity ratios together for Afghan commercial banks during 2014-2020. The research gap is, therefore, both geographic and empirical.

1. First, the study analyzes a balanced panel of ten Afghan banks instead of transferring conclusions directly from developed markets.
2. Second, it estimates a comprehensive panel equation that includes current bank indicators, ownership, lagged macroeconomic controls, and bank-level _LAGGED terms.
3. Third, it compares Pooled OLS with Fixed Effects and Random Effects using formal selection tests and reports additional panel diagnostics.
4. Fourth, it tests whether the main conclusions change with bank-clustered standard errors, winsorization, and leave-one-bank-out estimation.

The resulting contribution is deliberately limited to this sample and period. It adds transparent evidence from a fragile banking environment while avoiding claims that the model establishes causality, post-2020 conditions, or an optimal liquidity threshold.

3-Methodology

The study uses an annual balanced panel of 70 observations from 10 commercial banks over 2014-2020. Return on Asset (ROA) measures financial performance. The empirical specification contains eight current bank-level indicators (LCR, CASH_RATIO, OCFR, NWC/TA, TCD, L, RG, and CI), a government-ownership dummy (OWN), lagged inflation, GDP growth, and interest-rate controls, and eight bank-level _LAGGED terms. LCR is measured as the ratio of High-Quality Liquid Assets to net cash outflows over 30 days.

Pooled OLS was selected after comparing it with bank Fixed Effects (FE) and Random Effects (RE) for the same full equation. The poolability F-test fails to reject common bank intercepts ($F(9, 41) = .6296$, $p = .7650$). The Breusch-Pagan LM test also fails to reject the absence of a random bank effect (chi-square(1) = .7292, p = .3931). The Hausman test does not find systematic FE-RE coefficient differences (chi-square(19) = 3.0888, p = .99999). The Hausman test alone only indicates that RE is not contradicted; the LM result is what shows that an additional random bank intercept is not required. Taken together, the tests support Pooled OLS for this sample (Breusch & Pagan, 1980; Hausman, 1978; Greene, 2012; Hsiao, 2014).

The robustness assessment supplements the reported Durbin-Watson statistic with a Breusch-Pagan heteroscedasticity test, a Wooldridge-type test for first-order panel serial correlation, Pesaran's cross-sectional-dependence test, variance inflation factors (VIFs), Jarque-Bera residual normality, and Cook's distance (Breusch & Pagan, 1979; Drukker, 2003; Pesaran, 2004; Wooldridge, 2010). Because the heteroscedasticity result is close to the 10% level, bank-clustered standard errors are reported as a sensitivity check, with caution because there are only ten bank clusters (Cameron & Miller, 2015). Winsorized and leave-one-bank-out estimates provide further influence checks.

3.1 Model Specification

The following Pooled OLS panel equation is estimated:

$$ROA_{i,t} = \beta_0 + \beta_1 LCR_{i,t} + \beta_2 CASH_RATIO_{i,t} + \beta_3 OCFR_{i,t} + \beta_4 (NWC/TA)_{i,t} + \beta_5 TCD_{i,t} + \beta_6 L_{i,t} + \beta_7 RG_{i,t} + \beta_8 CI_{i,t} + \beta_9 OWN_i + \beta_{10} INFLATION_LAGGED_t + \beta_{11} GDP_LAGGED_t + \beta_{12} INTEREST_LAGGED_t + \beta_{13} LCR_LAGGED_{i,t} + \beta_{14} CASH_RATIO_LAGGED_{i,t} + \beta_{15} OCFR_LAGGED_{i,t} + \beta_{16} (NWC/TA)_LAGGED_{i,t} + \beta_{17} TCD_LAGGED_{i,t} + \beta_{18} L_LAGGED_{i,t} + \beta_{19} RG_LAGGED_{i,t} + \beta_{20} CI_LAGGED_{i,t} + \varepsilon_{i,t}$$

where:

$ROA_{i,t}$ denotes Return on Asset for bank *i* in year *t*;

$LCR_{i,t}$ is the Liquidity Coverage Ratio;

$CASH_RATIO_{i,t}$ is cash and cash equivalents divided by current liabilities;

$OCFR_{i,t}$ is operating cash flow divided by current liabilities;

$(NWC/TA)_{i,t}$ is Net Working Capital divided by Total Assets;

$TCD_{i,t}$ is Trend Cash Deposits, calculated as $(Cash_t - Cash_{t-1})/Cash_{t-1}$;

$L_{i,t}$ is Leverage, calculated as Total Debt divided by Total Equity;

$RG_{i,t}$ is Revenue Growth, calculated as $(Revenue_t - Revenue_{t-1})/Revenue_{t-1}$;

$CI_{i,t}$ is Capital Intensity, calculated as Total Assets divided by Revenue;

OWN_i equals 1 for a government-owned bank and 0 otherwise;

$INFLATION_LAGGED_t$, GDP_LAGGED_t, and $INTEREST_LAGGED_t$ are the lagged macroeconomic controls;

The _LAGGED suffix identifies the terms designated as lagged for the corresponding bank-level variables in the empirical specification, and β_0 through β_{20} are the estimated coefficients;

$\varepsilon_{i,t}$ is the idiosyncratic error term.

3.2 Estimation Framework

The equation is estimated on all 70 bank-year observations, and all variables are measured as defined in Table 1. The baseline results report conventional Pooled OLS standard errors and p-values. As robustness exercises, the same coefficients are re-evaluated with bank-clustered standard errors, continuous variables are winsorized at the 1st and 99th percentiles, and the equation is re-estimated after omitting each bank. Because temporal ordering is central to dynamic interpretation, coefficients on the bank-level _LAGGED terms are interpreted cautiously within the short annual panel.

3.3 Data and Variable Measurement

Bank-level observations were compiled from the annual reports and financial statements of the sampled banks. The sample covers New Kabul Bank, Azizi Bank, Afghanistan International Bank, Ghazanfar Bank, Afghan United Bank, First MicroFinanceBank-Afghanistan, Islamic Bank of Afghanistan, Maiwand Bank, Pashtany Bank, and Bank-e-Millie Afghan. The macroeconomic controls comprise inflation, GDP growth, and the interest rate. Table 1 presents the definitions and formulas used in the analysis.

Table 1. Variables, sources, and formulas

Variable (label)	Type	Source/formula
Return on Asset (ROA)	Dependent	Income Statement: Net income / average total assets
Liquidity Coverage Ratio (LCR)	Independent	Balance Sheet: HQLA / net cash outflows (30 days)
Cash Ratio (CASH_RATIO)	Independent	Balance Sheet: (cash + equivalents) / current liabilities
Operating Cash Flow Ratio (OCFR)	Independent	Cash Flow Statement: operating cash flow / current liabilities
Net Working Capital/Total Assets (NWC/TA)	Independent	Balance Sheet: (current assets - current liabilities) / total assets
Trend Cash Deposits (TCD)	Independent	Balance Sheet: $(Cash_t - Cash_{t-1}) / Cash_{t-1}$
Leverage (L)	Independent	Balance Sheet: total debt / total equity
Revenue Growth (RG)	Independent	Income Statement: $(Revenue_t - Revenue_{t-1}) / Revenue_{t-1}$
Capital Intensity (CI)	Independent	Balance Sheet: total assets / revenue
Ownership (OWN)	Control	1 for government-owned bank; 0 otherwise
Macroeconomic controls	Control	Lagged inflation, GDP growth, and interest rate

Note. Ratio variables enter the regression in ratio units. LCR is expressed as High-Quality Liquid Assets divided by net cash outflows over 30 days. Leverage is defined as Total Debt/Total Equity, and TCD denotes Trend Cash Deposits.

4-Results

Section 4 reports the descriptive statistics, panel-model selection tests, and full Pooled OLS estimates for the balanced panel of 70 bank-year observations. The selection tests support the pooled specification, and the estimated model is jointly significant ($F = 6.669216$, $p < .001$), with $R^2 = .731337$. At the 5% level, current Revenue Growth (RG) is positively associated with ROA and RG_LAGGED is negatively associated with ROA, whereas the remaining coefficients are not statistically significant. The results are, therefore, interpreted as conditional associations rather than causal effects.

4.1 Descriptive Statistics

Table 2. Descriptive statistics

Variable	N	Mean	Std. dev.	Minimum	Maximum
ROA	70	.0077	.0226	-.0359	.1631
LCR	70	2.9028	2.2716	.4800	9.8800
CASH_RATIO	70	.6362	.2097	.3401	1.3074
OCFR	70	.0748	.1373	-.3337	.4144
NWC/TA	70	-.5274	.6207	-1.6912	.6568
TCD	70	.1012	.2406	-.3092	1.0900
L	70	9.1080	6.3320	-6.7836	27.4858
RG	70	.1320	.5526	-.6952	2.8171
CI	70	24.9516	14.7288	7.8151	80.2965
OWN	70	.3000	.4616	.0000	1.0000

Table 2 shows meaningful variation across the 70 bank-year observations. Mean ROA is .0077 (approximately .77%), while LCR averages 2.9028. The broad ranges for NWC/TA, leverage (L), revenue growth (RG), and capital intensity (CI) indicate considerable differences across banks and years. These descriptive

figures summarize the sample only and do not establish the direction or statistical significance of the regression relationships.

4.2 Panel Model Selection

Table 3. Model-selection tests for the full Pooled OLS specification

Test	Null hypothesis	Statistic	df	p-value
Poolability F-test	Common bank intercepts	.6296	9, 41	.7650
Breusch-Pagan LM	No random bank effect	.7292	1	.3931
Hausman FE vs. RE	RE differences are not systematic	3.0888	19	.99999

Table 3 provides the direct econometric basis for choosing Pooled OLS. The poolability F-test fails to reject common bank intercepts ($F(9, 41) = .6296$, $p = .7650$), so the data do not provide evidence that bank-specific Fixed Effects are needed. The Breusch-Pagan LM test fails to reject the absence of a random bank effect (chi-square(1) = .7292, $p = .3931$), so the data also do not support adding a Random Effects component. The Hausman test finds no systematic FE-RE coefficient differences (chi-square(19) = 3.0888, $p = .99999$). Taken together, the F-test and LM test provide the principal empirical justification for Pooled OLS; the Hausman result is consistent with this choice but does not, by itself, select the pooled model.

4.3 Full Pooled OLS Estimates

Table 4. Pooled OLS estimates of the determinants of ROA

Variable	Coefficient	Std. error	t-statistic	p-value
Constant	0.007149	0.031538	0.226675	.8216
LCR	0.001683	0.001522	1.106360	.2740
CASH_RATIO	-0.017535	0.013195	-1.328961	.1900
OCFR	0.016788	0.015129	1.109638	.2726
NWC/TA	0.004124	0.004605	0.895419	.3749
TCD	0.011300	0.008080	1.398545	.1682
L	-0.000508	0.000385	-1.320622	.1928
RG	0.032211	0.004846	6.646815	<.001
CI	0.000149	0.000270	0.551924	.5835
OWN	0.003223	0.005640	0.571414	.5703
INFLATION_LAGGED	-0.001263	0.001198	-1.054251	.2969
GDP_LAGGED	0.000825	0.002143	0.385108	.7018
INTEREST_LAGGED	0.000959	0.002465	0.389179	.6988
LCR_LAGGED	0.001187	0.001790	0.663317	.5102
CASH_RATIO_LAGGED	-0.013900	0.013168	-1.055586	.2963
OCFR_LAGGED	-0.000700	0.012968	-0.054000	.9572
NWC/TA_LAGGED	0.006857	0.004926	1.392116	.1702
TCD_LAGGED	-0.000968	0.006452	-0.150018	.8814
L_LAGGED	0.000340	0.000393	0.866268	.3906
RG_LAGGED	-0.027078	0.005618	-4.819482	<.001
CI_LAGGED	-0.000009	0.000185	-0.050398	.9600

Note. Dependent variable: ROA. Method: Panel Least Squares (Pooled OLS). Balanced panel: 10 banks x 7 years = 70 observations. Conventional Pooled OLS standard errors and p-values are reported. Variable labels are standardized for readability.

Table 4 (continued). Model summary

Model statistic	Value	Model statistic	Value
R-squared	.731337	Mean dependent variable	.007709
Adjusted R-squared	.621678	S.D. dependent variable	.022585
S.E. of regression	.013891	Akaike information criterion	-5.47179
Sum squared residuals	.009455	Schwarz criterion	-4.79724
Log likelihood	212.5125	Hannan-Quinn criterion	-5.20385
F-statistic	6.669216	Durbin-Watson statistic	2.359729
Prob(F-statistic)	.000000	Observations	70

Table 4 presents the full Pooled OLS estimates. Current Revenue Growth (RG) is positive and statistically significant (beta = .032211, SE = .004846, t = 6.6468, p < .001). Holding the other regressors constant, a .10 increase in RG is associated with a .003221 increase in ROA, equal to about .322 percentage points. This is a conditional association, not a causal estimate.

RG_LAGGED is negative and statistically significant (beta = -.027078, SE = .005618, t = -4.8195, p < .001). Conditional on current RG and the other regressors, a .10 increase in RG_LAGGED is associated with a .002708 reduction in current ROA. The opposing signs of RG and RG_LAGGED may reflect timing, base effects, revenue volatility, or mean reversion; the regression cannot distinguish among these explanations.

No other coefficient is statistically significant at the 5% level in the baseline table. This includes the current and _LAGGED terms for LCR, CASH_RATIO, OCFR, NWC/TA, TCD, L, and CI, as well as ownership and the macroeconomic controls. TCD is positive in the current period (p = .1682), while CASH_RATIO and L are negative (p = .1900 and p = .1928), but these signs are not precise enough to support directional conclusions.

The model is jointly significant (F = 6.669216, p < .001) and reports R^2 = .731337 and adjusted R^2 = .621678. Thus, the included regressors jointly account for approximately 73.1% of the observed variation in ROA within this sample. A high R^2 does not mean that each liquidity variable is important, nor does it establish causation. The conclusion must, therefore, emphasize the two RG terms rather than a general statistically significant effect of liquidity management.

5. Discussion And Economic Interpretation

5.1 Revenue Growth as the Primary Driver of Profitability

The positive current RG coefficient is consistent with the view that stronger revenue generation can support profitability and asset use. Revenue diversification has also been associated with bank performance in emerging economies, although its benefits depend on institutional and bank-specific conditions (Sanya & Wolfe, 2011). The negative RG_LAGGED coefficient qualifies the current-period result. Because RG and RG_LAGGED are included simultaneously, the estimates describe a short-run conditional pattern rather than a simple statement that sustained revenue growth always raises profitability.

5.2 Liquidity Ratios and Profitability

The baseline estimates do not show a statistically significant effect for LCR, CASH_RATIO, OCFR, NWC/TA, or TCD. This contrasts with work that identifies nonlinear liquid-asset effects (Bordeleau & Graham, 2010; Mohammad & Khan, 2024) and with research linking liquidity creation to profitability in U.S. banks (Duan & Niu, 2020). It is, however, consistent with the broader finding that results depend on the proxy, period, and banking environment. In Afghanistan, high liquidity during the study period may have reflected low lending and limited investment opportunities rather than a profit-maximizing choice (World Bank, 2021). The insignificant coefficients do not prove that liquidity management is unimportant for solvency or regulation; they show only that this equation does not identify a reliable partial association with ROA for those variables.

5.3 Leverage and Profitability Trade-offs

Leverage (L), defined as Total Debt divided by Total Equity, has a small negative but statistically insignificant coefficient (beta = -.000508, p = .1928). The sign alone does not establish that debt reduced profitability or that Afghan banks followed a particular financing policy. The wide leverage range and observations affected by weak or negative equity also call for caution.

5.4 Macroeconomic and Working Capital Effects

The lagged GDP, inflation, and interest-rate coefficients are statistically insignificant. This should not be interpreted as evidence that Afghan bank profitability is insulated from the macroeconomy. The sample contains only seven annual periods, and each macroeconomic value is common to all ten banks in a year, so independent time-series variation is limited. Political uncertainty, weak credit demand, shallow markets, and high precautionary liquidity provide plausible reasons why Afghan results can differ from cross-country or developed-market findings (International Monetary Fund, 2019; World Bank, 2020, 2021). Those mechanisms remain explanations for future testing rather than effects identified by the present regression.

6-Diagnostic And Robustness Tests

Table 5. Diagnostic tests for the full Pooled OLS equation

Diagnostic	Statistic	p-value	Interpretation at 5%
Breusch-Pagan heteroscedasticity	chi-square(20) = 29.8853	.0717	Homoscedasticity not rejected
Wooldridge-type serial correlation	F(1, 9) = .0067	.9366	No evidence of AR(1)
Pesaran cross-sectional dependence	CD = -.4551	.6491	Independence not rejected
Variance Inflation Factor	Range 1.35-5.66	-	No severe VIF above 10
Jarque-Bera residual normality	chi-square = 4.3191	.1154	Normality not rejected
Cook's distance	9 above 4/n	-	Influence checks warranted

The selection tests were applied to the same full equation shown in Table 4. The poolability F-test (p = .7650) finds no evidence of different bank intercepts, and the random-effects LM test (p = .3931) finds no evidence that a random bank intercept is needed. The Hausman result (p = .99999) does not reject RE consistency, but it does not, by itself, select Pooled OLS. The combined F and LM evidence provides the direct econometric justification for pooling.

The Breusch-Pagan heteroscedasticity test gives chi-square(20) = 29.8853 (p = .0717). Homoscedasticity is not rejected at 5%, although the result is borderline at 10%. Conventional standard errors are, therefore, retained in the baseline table, while bank-clustered standard errors are reported as a robustness check. With only ten clusters, changes in clustered p-values must be interpreted cautiously.

The Wooldridge-type test does not reject the absence of first-order serial correlation (F(1, 9) = .0067, p = .9366), and the Pesaran CD test does not reject cross-sectional independence (CD = -.4551, p = .6491). VIFs range from 1.35 to 5.66, below the common threshold of 10, although current covariates and their _LAGGED counterparts create moderate collinearity. The Jarque-Bera statistic is 4.3191 (p = .1154), so residual normality is not rejected at 5%. Nine observations exceed Cook's-distance threshold 4/n; the largest is Bank-e-Millie Afghan in 2016.

Bank-clustered inference retains the positive RG result (p < .001) and negative RG_LAGGED result (p = .0036), but it also makes CASH_RATIO negative (p = .0168) and OCFR positive (p = .0431). This change reinforces the need for cautious wording. Winsorization retains both RG signs, while omitting Bank-e-Millie Afghan leaves current RG positive (p = .0404) but makes RG_LAGGED insignificant (p = .4379). The current RG association is, therefore, more stable than the RG_LAGGED association. The small sample, influential observations, and sensitivity of _LAGGED estimates to temporal specification remain important limitations.

Table 6. Sensitivity of the revenue-growth coefficients

Specification	RG beta (p)	RG_LAGGED beta (p)	R-squared
Baseline Pooled OLS, conventional SE	.032211 (<.001)	-.027078 (<.001)	.731
Baseline, bank-clustered SE	.032211 (<.001)	-.027078 (.004)	.731
Winsorized 1%/99%, clustered SE	.017463 (.001)	-.014415 (.011)	.561
Omit Bank-e-Millie Afghan, clustered SE	.017962 (.040)	-.008157 (.438)	.300

Note. Bank-clustered inference is based on ten clusters and should be treated cautiously. In the clustered baseline, CASH_RATIO is negative (p = .0168) and OCFR is positive (p = .0431); these sensitivity results are discussed alongside the baseline estimates.

7-Conclusion

This study examined liquidity management and profitability in ten Afghan commercial banks during 2014-2020. The full Pooled OLS specification yields an R^2 of .731337. Formal selection tests support pooling over bank Fixed Effects or a Random Effects intercept for this sample. In the baseline coefficient table, only current RG and RG_LAGGED are statistically significant at the 5% level.

The findings do not establish a general statistically significant profitability effect for LCR, CASH_RATIO, OCFR, NWC/TA, TCD, leverage, or capital intensity. Clustered and winsorized checks show some sensitivity in the liquidity coefficients, and the RG_LAGGED estimate is sensitive to Bank-e-Millie Afghan. The most defensible conclusion is, therefore, that current revenue growth has a positive and comparatively stable association with ROA, while the negative RG_LAGGED association is less stable and warrants cautious interpretation.

The study's contribution is a transparent bank-level examination of a fragile and under-researched banking system. For managers and Da Afghanistan Bank, the results support continued monitoring of liquidity buffers, data quality, stress resilience, and the sustainability of revenue growth. They do not support weakening Basel liquidity requirements or claiming that a particular liquidity ratio will automatically raise profitability. Afghanistan's shallow markets, weak lending opportunities, and institutional uncertainty help explain why its results may differ from those in developed or diversified banking systems.

Future research should construct lagged variables from explicitly ordered bank-year panels, extend the sample beyond 2020, and use quarterly observations where reliable data are available. Larger samples could test nonlinear liquidity effects, bank-time fixed effects, dynamic-panel estimators, and stronger small-cluster inference. These extensions would help separate causal mechanisms from the conditional associations reported here.

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Low Productivity in Nigeria: Trends, Drivers and Long-Term Policy Options

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Abstract

Despite the large population, natural-resource endowment and periods of strong aggregate output growth in Nigeria, productivity has remained low and has further lost momentum since the mid-2010s.Persistently low productivity levels and growth trends have therefore become a major macroeconomic issue for research and policy. In this paper, we examine the persistence, structure and developmental consequences of low productivity in Nigeria. Specific long-term policy options for reversing the country's weak performance are also identified. The study documents the long-run trajectory of aggregate and sectoral productivity, synthesises the theoretical and empirical drivers of productivity, and applies the insights to the design of a coherent reform agenda. The analysis combines descriptive examination of macroeconomic and sectoral indicators with evidence from neoclassical, endogenous-growth, human-capital, institutional and structural-transformation perspectives. The evidence reveals a pronounced productivity paradox for Nigeria where scale and potential coexist with

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inefficiency and stagnation. Sectoral patterns show that agriculture continues to employ a large proportion of workers while generating the lowest value added per worker while industrial and manufacturing productivity have declined in recent years. The paper attributes these outcomes to inadequate capital deepening, poor infrastructure, weak human-capital formation, financing constraints, and institutional weaknesses. The paper argues that restoring productivity growth requires deep strategy that links short-term macroeconomic stabilisation to sustained structural reform. The paper therefore concludes that productivity should become the organising principle of Nigeria's development strategy.

1. Introduction

Productivity isn't everything, but in the long run it is almost everything

Paul Krugman (1990)

The Age of Diminished Expectations

Both theory and evidence support the belief that significant long-run gains, even if not permanent changes in the growth rate, can be achieved by increased investment in the broadest sense, including human capital, technological knowledge, and industrial plant and equipment.

Robert Solow (1992)

Nobel Prize Winner in Economic Sciences

Increasing jobs more than output implies a fall in productivity and standards of living. That surely cannot be our goal.

Alan Greenspan (2011)

Former Chairman of the Board of Governors of the Federal Reserve

Nigeria is Africa's largest economy by population. This, combined with other factors, presents a useful potential for the country to extend beyond its current status in the global landscape. As of mid-2025, the country boasts a nominal GDP of approximately $188.27 billion that positions it as one of the continent's largest economies by GDP and the among the top 50 economies in the world. There has

been a significant rebound in the economy since the slum during the Covid 19 era, with real GDP growth accelerating to 3.9% year-on-year in the first half of 2025. This growth is largely driven by expansions in services (up 4.5%) and non-oil sectors like ICT and financial services as reported by the National Bureau of Statistics (NBS). Underpinning this economic stature is a possible demographic dividend that could propel Nigeria toward middle-income status. The country's population currently stands at over 230 million, with over 60% under the age of 25 (World Bank, 2025). This youthful bulge, which is projected to add 27 million to the labour force by 2030, tends to align with the "Asian Tigers" pathway in terms of economic transition. In this pattern, youth population spurs significant human capital development that fuels rapid industrialisation and income growth. In Nigeria, however, this promise of labour-led economic prosperity has largely been unrealised due to deep structural barriers that have converted demographic vigour into a liability rather than an asset. This structural deficiency in the economy is initially traced to the nation's oil wealth (which currently accounts for over 80% of export earnings according to CBN figures) which has historically masked deeper vulnerabilities. Although there are signs of significant restructuring of the economic base in the last two years, the structural cracks in the economy have reflected in the pattern of labour productivity and overall economic performance in the country.

At the heart of Nigeria's economic narrative therefore lies a stark productivity paradox where scale and potential coexist with inefficiency and stagnation. Aggregate labour productivity, which is technically measured as GDP value added per employed person, is a crucial indicator of the level of economic performance (Dieppe, 2021). Productivity growth is also the key driver of sustainable income growth and poverty reduction (Zymek, 2024; Panizza, 2021). From another perspective, productivity relates to efficiency in economic performance and considers the amount of output derived while using available (and often limited) resources. That is why less than 2% of the US population who are farmers sufficiently feed over 350 million people while 40% of Nigeria's population who are farmers cannot field 230 million people. Indeed, as Bhatt (2024) noted, productivity is a foundation of prosperity. This shows that in terms of agriculture, the US is able to produce more with existing or fewer resources. This is what productivity explains. For developing economies like Nigeria, the productivity agenda is even more central. The ability to generate higher value added per worker determines the pace at which structural transformation occurs, the speed of poverty reduction, the capacity to absorb a rapidly growing labour force and ability to raise standard of living sustainably.

As much as productivity is crucial for economic long-term progress, available data indicate that it has been low in Nigeria. Aggregate productivity in Nigeria was $11,800 (in 2021 PPP terms) in 2024. This is equivalent to $2,800 annually, a figure that has barely budged in over a decade and has paled against regional benchmarks like South Africa's $10,200 per worker in 2024. According to the World Bank, global productivity averaged $49,000 (in 2021 PPP terms) in 2024. This metrics reveals that the average Nigerian worker generates just $7 per hour, compared to Gabon's $26 or Botswana's $21, and South Africa's $30. Thus, even within the African region, Nigeria's productivity has remained low. The growth rate of productivity in Nigeria has also been slow. For instance, average growth was 1.25% between 1990 and 2024 (World Bank, 2024). This growth rate is below the 3.5% average that is needed to absorb the 3.5 million annual labour market entrants. Nigeria's average productivity growth since the 1990s is also lower than the global average of 1.94% over the same period. The slow productivity growth in Nigeria has occurred in spite of the largely taunted slowdown in global productivity since the late 2010's. Indeed, the leading economies in Africa that have effectively redirected their fortunes, and largely reduced poverty rates have experienced very strong productivity bursts in the last few decades. For instance, productivity has grown on average by 3.77% and 2.93% for Rwanda and Ghana respectively since 1990. By 2023, total factor productivity in Nigeria had contracted by 0.5% yearly. The decline was mainly driven by capital misallocation, with 60% of investments funneled into extractives rather than human capital or infrastructure (ILO, 2024).

A major factor in the productivity challenge in Nigeria is the large disparities in sectoral performance. In particular, the agricultural sector employs 40% of the workforce but contributes only 22% to GDP. The sector is dominated by smallholder farmers who are reliant on rain-fed subsistence operations amid heightening climate shocks and recent insecurity issues. Yields from these farmers are 30-40% less than those mechanised and more modern counterparts in other countries (Brookings Institution, 2025). Similarly, the share of manufacturing in total output has stagnated at 12% for decades. Indeed, incessant power outages is estimated to cost firms up to $29 billion annually or 6% of GDP (World Bank, 2025). This paradox of segmentation and internal disparities is more vividly illustrated in urban hubs like Lagos where fintech unicorns like Flutterwave generate billions in value-added output, yet coexist with informal markets where traders eke out $2 daily amid 40% logistics costs (which is four times the global average). The result of all these is that only 20% of Nigerians hold "productive" jobs in formal, high-output and high-wage sectors leaving 80% trapped in low-productivity and informal roles that perpetuate a cycle of underinvestment

aggregate low living standards (World Bank, 2025). In essence, Nigeria's economy expands like a balloon with a slow leak which is impressive in volume, but deflated by inefficiency.

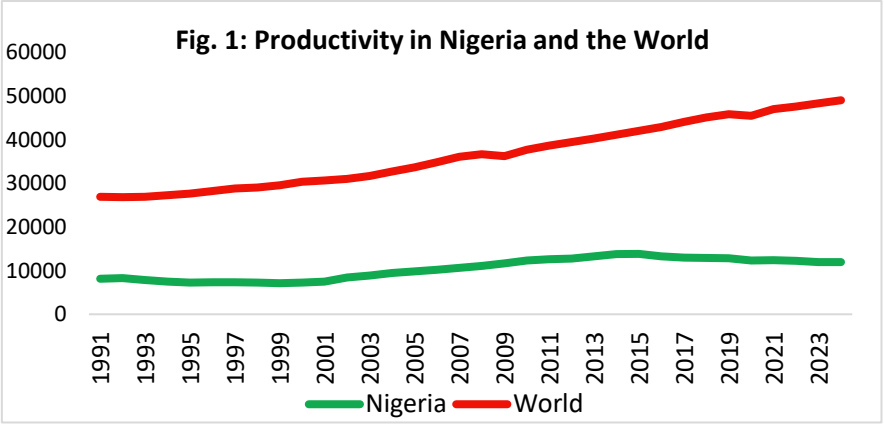
The economic toll of the productivity malaise in Nigeria has manifested in foregone GDP potential which is estimated at 2-3% annually – equivalent to $4-6 billion in untapped output (African Development Bank (AfDB), 2025). Based on empirical estimates like (Dieppe, 2021), the potential GDP losses compound through multiplier effects. It is estimated that each 1% productivity shortfall erodes 0.5% in fiscal revenues. This further imposes significant strain on the national budget which is already overburdened by debt servicing with scant room for social spending. Inadequate social spending directly links to the rising wave of poverty in the country. As indicated in the NBS report of 2022, 63% of persons living within Nigeria (133 million people) are multidimensionally poor. It is projected that the figure has risen significantly since then. Because of the low productivity of the economy, youth unemployment and under-employment have also been high at 8.6% and 47.5% respectively.

Thus, Nigeria’s productivity challenge is a human tragedy where a vibrant populace and resource-bountiful nation yield diminishing returns amid entrenched inefficiencies. As the world eyes Africa’s rise, Nigeria’s ability to transcend this impasse will not only define its trajectory, but also the continent’s shared future. There is therefore a need to examine how this challenge of low productivity in the country can be reversed to ensure a significant shift from a survival system to sustainable value creation. This is the main focus of this study. Three objectives guide the paper. First, the study documents the empirical trajectory of productivity in Nigeria using publicly available macroeconomic and sectoral data. Second, it synthesises theoretical perspectives to frame the determinants and implications of productivity in developing-country contexts. Third, it applies these frameworks to the Nigerian case to explain the persistence of low productivity and propose policy measures that can shift the economy toward higher productivity growth over time.

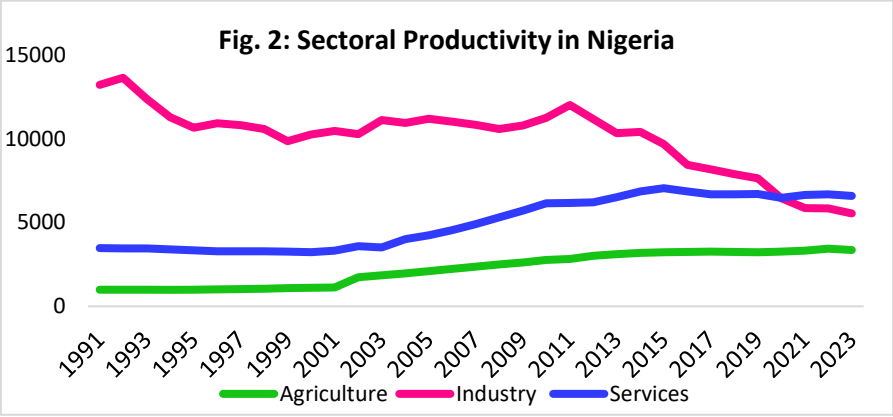
2. The State of Productivity in Nigeria

To understand Nigeria’s productivity challenge, it is essential to examine the long-run evolution of key indicators that proxy labour efficiency, output per worker and sectoral value creation. Trends in productivity in Nigeria along with the global level are reported in Figure 1. Productivity in Nigeria has hovered around $8,000–$13,000 between 1990 and 2024. This is a minimal upward trajectory despite oil

booms in the early 2000s and post-2020 reforms. Indeed, productivity dropped from close to $13,000 in 2014, and to $11,900 in 2024. This pattern also suggests that gains in labour productivity have occurred, particularly during the late 2000s and early 2010s. The leveling off after 2014 and the difficulty of sustaining strong upward trajectories reflect both macroeconomic fragilities and structural constraints in Nigeria's productive capacity. In comparison, average world productivity surged through the entire period, from $27,000 in 1991 to close to $50,000 by 2024.

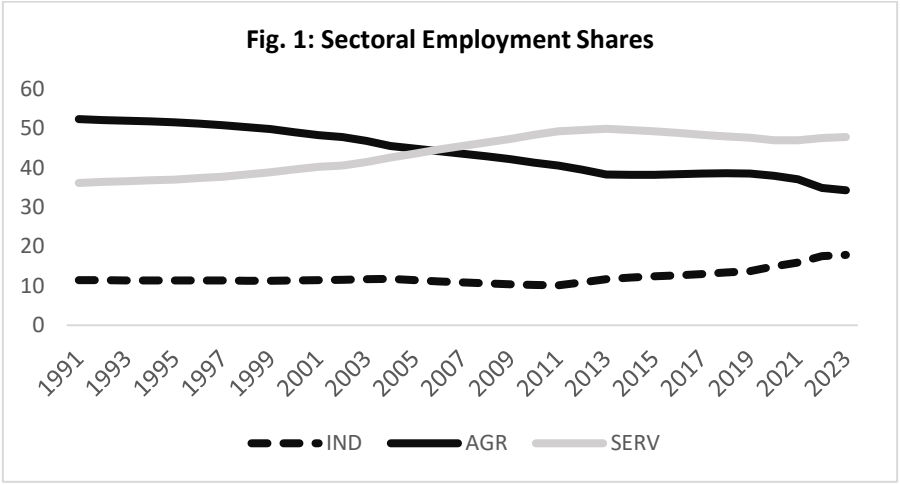


To unpack productivity more granularly, sectoral value-added per worker (or per employed person) provides insight into how different sectors contribute to labour productivity in the country. Agricultural productivity shows a slow but steady rise from the early 2000s, and it is lowest among the three sectors. This indicates that the largest employer of labour in Nigeria exhibits the lowest productivity outcome. It should also be noted that agriculture has the highest rate of informality and limited technological adoption. Industrial productivity, which historically serves as the main driver of productivity gains, displayed a long-term decline that dipped sharply after 2014. This downturn aligns with deindustrialisation pressures in Nigeria, where the contribution of manufacturing has either remained constantly low or declined in the last few decades. Several macroeconomic and institutional factors like persistent foreign exchange constraints and energy shortages have contributed to the slow collapse of key manufacturing subsectors in the country.

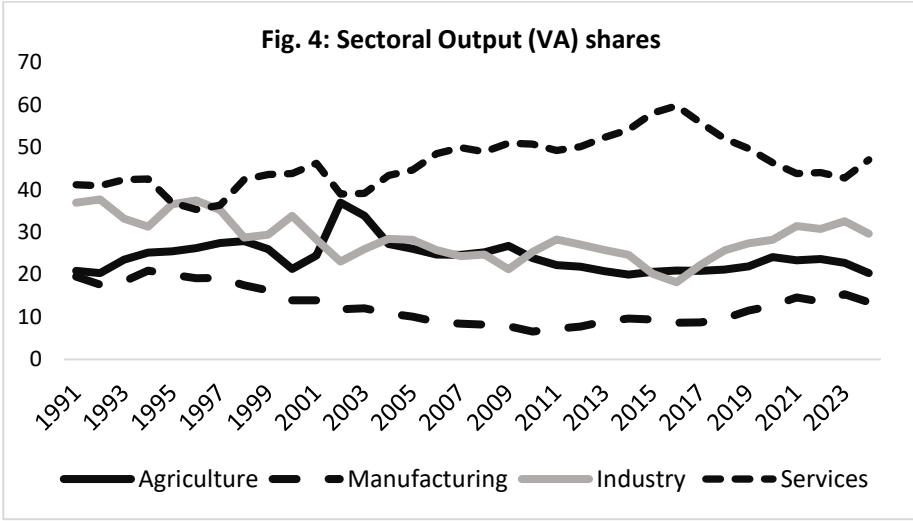


The services sector has seen the biggest movement in both employment and productivity activity since the 2000s. Productivity has increased even though the sector has experienced the greatest influx of labour over the period. The productivity gains in the sector have, however, been limited to modern sub-sectors in finance, ICT and entertainment. Interestingly, these sub-sectors are limited in terms of employment capacity. Majority of the labour in the services sector is therefore concentrated in low-productivity and highly informal traditional segments. This also reflects the dominance of low-productivity informal services rather than high-value modern services in the Nigerian economy. Essentially, sectoral evaluation of productivity in Nigeria presents a picture where labour is concentrated in low-productivity activities.

Further outlook on the productivity status in Nigeria evaluates the dimensions of the main components of employment and output. Figure 3 depicts the evolution of sectoral employment shares in Nigeria. Agriculture is the dominant employer throughout the period, although its share has declined steadily from above 50% in the early 1990s to 30% range by 2024. This gradual decline is typical of structural transformation. However, the persistence of such a large agricultural labour share, despite the sector's very low productivity, indicates slow movement of workers into higher-productivity activities. There is evidence that services have absorbed much of the labour exiting agriculture, rising from 35% in the early 1990s to above 45% by 2024. However, this expansion is largely driven by informal and low-productivity services rather than modern tradable services. Industrial employment was mainly stagnant over the period, fluctuating between 10% and 15%. This also shows that Nigeria has not undergone meaningful industrial participation (per labour shares) over the period. This employment pattern with high agricultural labour share, weak industrial absorption and expansion of low-value services help explain Nigeria's persistently low productivity growth.



The chart on sectoral value-added (VA) shares in Figure 4 reveals Nigeria's long-standing structural imbalance in terms of output shares. Services consistently dominate output over the period. The share of services in total VA reached 60% in 2016 before moderating to 47% in the last three years. Much of the modern services in sub-sectors have been known to exhibit limited productivity spillover effects when compared with manufacturing (Rodrik & Sandhu, 2025). The share of value added in agriculture was also large over the period, although it was overtaken by industry in 2017. This shows that the sector with the second largest labour employment is actually the third largest in terms of value addition in the economy. This indicates very low productivity outcomes for the sector. Manufacturing shows a persistent decline from roughly close to 20% in the 1990s, and to below 10% in recent years. This clearly signals deindustrialisation and weak manufacturing competitiveness in the Nigerian economy. Moreover, the share of industry VA (which includes oil and gas sub-sector) exhibited strong volatility over the period, declining from a share of 35.3% in 1996 to 18.2% in 2016. Overall, the VA composition shows Nigeria's failure to sustain a productivity-enhancing structural transformation that is driven by manufacturing and high-value tradable sectors.



3. The Need for Productivity Growth?

Productivity growth, which is defined as the ability to produce more output with the same or fewer inputs, is the foundation of sustained economic progress in any nation. Its importance in shaping long-run living standards is one of the most robust conclusions in modern macroeconomics. From the Solow-Swan model to the endogenous growth literature, the consensus is clear that increases in output per worker explain the overwhelming bulk of differences in income levels across countries (Solow 1956; Romer 1986; Aghion & Howitt 1992; Mester, 2015; Kim & Loayza, 2019; Dieppe, 2021; Li &Noureldin, 2024). For an economy like Nigeria, where structural inefficiencies have long suppressed potential despite abundant human and natural resources, productivity growth is not simply desirable, rather, it is essential for achieving inclusive and sustainable economic transformation. In the last two decades, the Nigerian economy has grown in absolute terms in most years. Yet the output per person employed has stagnated or declined for much of the period. With a young population that is rapidly transiting into the labour market and continued low productivity in major sectors, the prospects for large-scale reduction in in underemployment and poverty in the near future remains unattainable.

In this study, eight major reasons for the centrality of productivity growth being central to Nigeria's development agenda are outlined. First, there is evidence that productivity growth is the primary long-run determinant of living standards. Modern growth theory has demonstrated repeatedly that differences in income per person across countries are overwhelmingly explained by differences in total

factor productivity, not by differences in capital intensity or labour force size alone. Thus, capital deepening alone cannot account for cross-country differences in living standards. Instead, differences in productivity performance explain most of the gap between rich and poor nations (Klenow & Rodriguez-Clare 1997; Kim & Loayza, 2019). Nations that sustained 2-3% annual productivity growth over decades (e.g., South Korea, Singapore and Vietnam) transformed from poor to rich status within a single generation (World Bank, 2022). Nigeria, by contrast, has experienced near-zero total factor productivity growth since the mid-2000s. The result is that even when GDP expands, the gains are swallowed by population growth and inefficiency, leaving the average real incomes essentially flat. Indeed, without deliberate productivity enhancement, Nigeria's recent macroeconomic stabilisation achievements may prove ephemeral.

Very importantly, the productivity growth is the engine of structural transformation in an economy. Structural transformation denotes the reallocation of labour and resources from low-productivity sectors (largely subsistence agriculture and petty services) into higher-productivity activities (manufacturing and modern services). The classical Lewis model and subsequent empirical work show that it is sustained and sharp increase in agricultural productivity that eventually drives into modern sectors of the economy for greater diversification. Moreover, labour aggregate productivity rises most rapidly when labour moves into activities with substantially higher value added per worker (Lewis 1954; McMillan & Rodrik 2011). In other words, without rising productivity in the tradable and capital-deepening sectors, labour shifts (even if they occur) will not generate durable increases in aggregate output per worker. Nigeria's persistent high share of employment in low-productivity agriculture and informal services therefore illustrate the danger of a growth path that lacks productivity-led sectoral upgrading. Thus, productivity growth is the necessary condition that makes structural transformation both possible and beneficial. This is because it creates the wage premium and firm profits that attract labour and capital into modern sectors. This further enables reallocation to raise aggregate living standards (Mester, 2015).

Furthermore, productivity growth is the main proven mechanism or channel for attaining large-scale poverty reduction in developing countries. History shows that no country has lifted tens of millions out of poverty without moving workers from low-productivity subsistence activities into higher-productivity modern sectors while simultaneously raising output per worker within each sector. The East Asian miracles achieved exactly this dual transformation. In the region, rising productivity in manufacturing and export-oriented activities contributed to rapid income growth and mass poverty reduction between the 1960s and 2000s (World

Bank, 2022). In Nigeria today, approximately 70% of the workforce remains trapped in low-productivity agriculture and informal services, generating incomes that keep households below or near the poverty line. The post-2023 reform period has seen real wages collapse and poverty headcount rise to levels, which has not seen in decades. Productivity growth provides and effective platform for reversing this trend by enabling firms to pay higher real wages without losing competitiveness, thereby putting more purchasing power in the hands of ordinary Nigerians and breaking the intergenerational transmission of poverty.

An important explanation for why productivity growth is essential for structural transformation and poverty reduction is the fact that productivity growth directly drives the real wage increases. Furthermore, the real wage increase is the most reliable route to shared prosperity (Erumban, & de Vries, 2024; Saidou et al, 2023; World Bank, 2022). When output per worker rises, firms can afford to pay higher wages while maintaining or improving profit margins. Episodes of rapid productivity growth are almost always accompanied by sustained real wage growth. Conversely, periods of stagnant productivity produce stagnant or falling real wages. The challenge of real wages is real in Nigeria. According to ILO report (2024), formal sector real wages have declined by more than 40% in purchasing power since 2019 in Nigeria because productivity has not kept pace with inflation and currency depreciation. Raising productivity in critical sectors like agriculture, agro-processing, light manufacturing, logistics and digital services would directly allow Nigerian workers to earn significantly more for the same effort. This dramatically improves living standards for the bottom half of the income distribution and expands the domestic market.

Productivity growth in the economy is also indispensable for absorbing the massive youth bulge into decent and productive employment in Nigeria. According to ILO (2024), 3.5-4 million young people enter the labour market annually. To realise any form of dividend from this demographic change, the economy must create not just any jobs but jobs that pay living wages and contribute to national wealth creation. There is, however, a prevalence of low-productivity firms that are small, informal and technologically stagnant in Nigeria. These firms find it difficult to scale or employ in large numbers (Nwaka and Emeagwali, 2024). A prevalence of high-productivity firms in the country, by contrast, will ensure increased aggregate invest, boost innovation, increase the size of the formal economy and maintain sustainable growth. Thus, the current economic trajectory in Nigeria, where underemployment affects over half the workforce, can only be altered by deliberate productivity-enhancing policies in labour-absorbing sectors like agro-allied industries, construction, clothing and

digital sectors as well as in the renewable energy industry. This will ensure that a mass of the labour force is employed in jobs with high-yielding income.

Furthermore, productivity growth strengthens macroeconomic stability and reduces vulnerability to external shocks. Low productivity economies often face macroeconomic fragility including fiscal deficits, recurrent balance-of-payments pressures and low domestic revenue mobilisation. Nigeria's experience over the past three decades has reflected this pattern. Until very recently, episodes of oil price decline had repeatedly exposed structural weaknesses in the economy that had persistently resulted in slowed growth and currency pressures. Higher productivity can reduce these vulnerabilities by helping to broaden the tax base. Indeed, productive firms are more formal and capable of generating corporate tax revenue. Evidence across Sub-Saharan Africa shows that tax-to-GDP ratios rise sharply with structural transformation and productivity gains (Bahar, 2017). Increased productivity also improves stability by enhancing external competitiveness. In particular, productivity determines export performance and the ability of firms to compete globally (Adegboye & Iweriebor, 2018). Countries that experience rapid productivity gains often see improvements in manufacturing exports and diversification. This helps to reduce dependence on volatile commodity revenues and create fiscal space and external buffers against shocks.

A major challenge for attaining sustainable development in most African countries is the mass deficiency in technology and innovation capacity. Productivity growth can, however, enable technological catch-up and position the country favourably in the 21st-century global economy. In an era of artificial intelligence, automation and green transformation, countries that fail to raise productivity rapidly will be relegated to the periphery of global value chains. Evidence from growth accounting shows that middle-income countries that are able to sustain rapid total factor productivity (TFP) growth do so by accelerating technology absorption and improving the efficiency of domestic firms (Rodrik 2013; IMF 2019). Similar economies to that of Nigeria (e.g., Vietnam, Bangladesh and Ethiopia) have all used productivity-enhancing industrial policies to capture shares of global manufacturing and textiles markets. On the other hand, Nigeria, despite its size and location, remains marginally integrated into these global value chains. Sustained productivity growth that targets skills upgrading, R&D incentives and digital infrastructure would allow Nigerian firms to move from the lower ends of the value chain like assembling imported components to the higher ends like product design and export.

Finally, although typically discussed in the context of firms and sectors, productivity matters for the public sector as well. Efficient governance is

fundamental to sustaining economic transformation. A large body of research shows that countries with strong state capacity tend to exhibit higher productivity outcomes (Acemoglu et al, 2019). Efficient public institutions deliver infrastructure, regulation, education, and health services at lower cost and higher quality, crowding in private investment. Productive private firms generate the revenues needed to fund better public services. This positive feedback loop is what transformed Mauritius, Botswana, Malaysia, and Rwanda from low-income to upper-middle-income status (Somani, 2021). Nigeria possesses every necessary ingredient to ignite the same virtuous cycle. What has been missing is a national consensus where productivity growth is the overriding priority. Until that consensus is forged and translated into coherent and sustained policy action, Nigeria will continue to grow below its potential and thus leaving hundreds of millions in preventable poverty.

4. Drivers of Productivity

Understanding the drivers of productivity is central to explaining the problems of low productivity and engendering new regimes of productivity growth in Nigeria. Economic theory offers multiple frameworks that illuminate how productivity emerges, how it evolves, and why it diverges across settings. Thus, the drivers of productivity are best understood through a synthesis of several influential theoretical traditions. In the neoclassical growth framework, long-run output per worker depends on capital deepening and exogenous technological progress such that sustained productivity gains require either higher steady-state capital per worker or faster technological advancement (Moseley, 2015; Solow 1956). Endogenous growth models shift this logic by showing that persistent increases in total factor productivity can arise internally from R&D investment, knowledge accumulation and innovation-driven creative destruction. Consequently, policies that support research activity and enhance diffusion channels are central to long-run productivity growth (Romer 1990; Aghion & Howitt 1992).

The human-capital-based extensions further argue that education and skills raise worker productivity directly and also complement physical capital and technological adoption (Lucas 1988; Mankiw et al, 1992). Institutional and political-economy perspectives highlight that property rights, contract enforcement and predictable regulatory environments shape incentives for investment and innovation. This means that weak or unstable institutions reduce expected returns to productive activity and slow technological upgrading (North 1990; Acemoglu & Robinson 2012). Further to this, the structural transformation literature emphasises that aggregate productivity rises when labour reallocates

from low-productivity agriculture into higher-productivity manufacturing and tradable modern services (Rodrik 2016).

At the empirical level, Dieppe (2021) classified the main drivers of productivity into three broad categories including:

- *Proximate sources* which are the direct mechanisms through which output per worker or TFP increases. These are the observable and quantifiable drivers that raise productivity at the firm, sector or economy-wide level. They are the direct factors that raise productivity today. Including innovation, physical capital and the quality of the labour force.
- *The supporting environment* which is why a country is able or unable to raise productivity. These include institutions, infrastructure, policies, and social conditions in a country.
- *Improvements in firm-level factors* which are the firm-level-specific conditions in an economy. These include innovation capabilities, input quality and regulations acting at the firm or market level

4.1 Proximate sources of growth

Innovation and technology transfer. Firms innovate by introducing new products and better ways to produce existing goods and services. As a result, overall productivity is likely to rise (Dieppe, 2021). The role of research and development (R&D) activity in a country like Nigeria differs compared to countries already at the technological frontier. New patents, which are one of the measures of R&D outcomes, tend to be more closely associated with productivity growth in countries with highly educated and skilled workers. Even when human capital is less developed, improvements in productivity can be achieved, despite being at a lower rate (World Bank 2018). In addition, R&D activity can enhance the absorptive capacities of firms and their ability to assimilate new technologies (Cohen & Levinthal, 1990). Low-income countries can also benefit from the diffusion of technologies across national borders.

R&D spending in Nigeria has revolved around 0.2-0.3% of GDP in the last decade. This ratio is far below the 1-2% in emerging peers like Vietnam and Indonesia. This case for Nigeria has resulted in slow technology diffusion. However, bright spots exist in fintech and digital services where startups like Paystack and Flutterwave have boosted sectoral productivity by over 20% through mobile money and e-commerce platforms. The National Digital Economy Policy aims to raise the contribution of ICT to GDP value added share to 20% by 2030.

A major limiting factor in this direction is the low broadband penetration (less than 70%) rate and digital access gap in the country.

Physical capital. Since Solow (1956), standard growth models have linked the height of the long-run growth path to the rate of investment. In many economies in East Asia and Pacific (EAP), rapid output growth has been closely linked to high investment. In the empirical literature, there is a robust cross-section association between the investment rate and labour productivity (Gradzewicz, 2020; Beaudry et al, 2005). Also, most private sector firms rely on services provided by infrastructure. Investment in infrastructure can complement new technologies, and raise productivity and well-being Martins (2019). Infrastructure needs in Nigeria are high and relate to transport, water and sanitation, power and telecommunications. In particular, insufficient energy infrastructure that results in frequent outages tends to reduce operating hours and increase cost of production through diesel/fuel and maintenance. This lowers productivity and competitiveness of firms as well as the incentive to invest in capital that requires stable power. As Vorisek and Yu (2020) have noted, achieving infrastructure-related Sustainable Development Goals in a country like Nigeria will require average yearly investment of 2 to 8 percent of GDP during 2020-40. It should be noted that the contribution of capital accumulation to output growth has been higher for low-income countries than for advanced economies (Dieppe, 2021).

The quality of labour (human capital). The productivity of an economy depends partly on the quality of its labour force, which can be improved in several ways. Other things being equal, a better-educated and healthier labour force will contribute more to economic activity. Education can enhance not only skills but also the ability to adopt new technologies. In the long term, education may have wider positive effects on the nature of civil society and the effectiveness of governments. Similarly, workers who are more educated, better trained and more highly skilled are better placed to contribute to technological advances and to help absorb new technologies, including ones from abroad (Dieppe, 2021). Since the 1980s, there has been a substantial increase in school enrolment although there is still a wide gap in terms of educational quality in the country. Also, better health raises labour productivity. Healthy workers tend to be more efficient, faster learners and more committed to improving their skills (World Bank 2018b). Essentially, good health complements education and reinforces the supply of high-quality labour.

In Nigeria, human capital deficiencies represent a binding constraint on productivity growth. Only about 10-12% of the workforce possesses tertiary education in the country, and skill mismatches leave millions underemployed

despite the country's youth bulge. The World Bank's human capital index for Nigeria stands at 0.36 in 2025 which means that a child born today will reach only 36% of potential productivity. Several childhood and tropical health challenges like stunting (affecting 37% of children) and malaria burdens have contributed to this low outcome. Health shocks alone reduce labour productivity by up to 10-15% annually in Nigeria (WHO, 2024). In the same vein, investments in vocational training and digital literacy, as seen in pilots by NITDA, could yield 20-30% productivity dividends.

Demographic factors. One demographic factor affecting labour productivity is the age composition of the labour force. New technologies may be adopted faster in economies with younger labour forces. Compared to more experienced workers, the expertise of younger workers is less tied to older technologies. Evidence suggests that economies with higher young or working-age population shares adapt more readily to new technologies, skills and organizational structures (Dieppe, 2021; Liu & Westelius 2017). Younger and working-age population shares have increased significantly in Nigeria since the 1980s. This presents a unique structure for reaping demographic dividends and productivity gains, especially if the youth population is well equipped for the modern future.

4.2 The supporting environment

Institutions. North (1991) defined institutions as "the rules of the game in a society, or the humanly devised constraints that shape human interaction. They consist of both informal constraints." Institutions include the rule of law, the legal system, and regulatory barriers to the creation and operation of firms. Institutional considerations are often invoked to explain why TFP and labor productivity vary across countries. Productivity growth in economies with relatively good institutions tends to be more stable than where institutions are weaker.

Macroeconomic stability. This is another environmental factor that drives productivity. Macroeconomic instability can form a binding constraint which limits the benefits of other drivers. Uncertainty in the macroeconomic environment can deter investment and cause capital outflows from a country (Dieppe, 2019). There is also evidence that, in stable macroeconomic environments, the effect of investment on output is stronger and measures of institutional quality have more explanatory power as determinants of productivity growth.

Income inequality. Most empirical studies that link growth to income inequality find that inequality has an adverse effect. In particular, Adegboye (2015) found

that inequality reversely hinders productivity growth in Nigeria in the long run. A more recent study finds that lower inequality (after taxes and transfers) is associated with faster and more durable growth, and that redistribution does not have an adverse effect on growth unless it is extreme (Berg et al. 2018).

Gender equality. Disparities between women and men (in access to education, health care, and earning opportunities) can lower overall productivity and national income. Improved earning opportunities for women can increase human capital and physical capital investment through higher income and higher returns to the human capital of women (Dieppe, 2021; Klasen & Santos Silva, 2018). Improved female access to education and earning opportunities will also tend to lower fertility, and fewer children per family can mean that each child receives better education and health care. Similarly, the productivity of women in farming and business can be constrained by unequal access to finance and weaker property rights protection. Female farmers have been found to be less productive than men in Nigeria (IITA, 2024).

Economic complexity. Complexity reflects diversification and production capabilities, and may be linked with higher productivity or greater scope for future growth (Diao et al, 2019) Producing more complex goods may also promote technological diffusion and convergence.

Foreign direct investment. Inflows of foreign direct investment (FDI) can promote productivity growth through improved organisational structures and management practices as well as advanced technology. As a source of capital, FDI should raise labour productivity and wages, especially for host countries with a high development level and high-quality institutions (Dieppe, 2021).

Finance. Financial depth is often linked with higher labour productivity (Levine & Warusawitharana, 2021; Adegboye & Iweriebor, 2018) and faster productivity growth (Didier & Cusolito, 2024). Well-developed financial markets can improve the efficiency of capital allocation and enable firms to make productivity-enhancing investments. They may also allow firms to diversify investment risk and increase liquidity, and to stimulate entrepreneurship.

5. Tackling Low Productivity in Nigeria

The discussion so far in this study has demonstrated that productivity is low in Nigeria and that this situation is linked to the poor status of the main drivers of productivity in the economy. Tackling low productivity in Nigeria, however, demands a comprehensive strategy that addresses root causes while also

leveraging the country's demographic and resource-related advantages. In the first place, the ongoing macroeconomic stabilisation moves of President Tinubu's administration, especially in terms of the correction of fuel prices and the naira exchange rate, have created some fiscal space within which public policy and fiscal measures can be exercised in influencing the direction of productivity in the country. It should be noted that although there have been noticeable improvements in output growth since the inception of the current reforms, productivity itself has remained unsatisfactorily low. This low productivity has, in turn, constituted a further binding constraint on inclusive growth. Therefore, a comprehensively successful approach must combine short-term quick wins with long-term structural transformation like those experienced in high-performing peers like Vietnam, Rwanda and Indonesia through deliberate investments in human capital, infrastructure and institutions. This requires political will as well as private-sector leadership and international partnerships to shift resources from low-value informal activities to high-productivity sectors.

Specifically, structural transformation that diversifies the economy away from oil and the primary industry is a foundational step in boosting productivity in Nigeria. Oil still accounts for over 80% of exports and over 30% of government revenues despite contributing less than 10% to GDP. This exposes the economy to volatility that crowds out non-oil investments. In diversifying away from oil, Nigeria must aggressively promote agro-processing, light manufacturing and digital services sectors. The African Continental Free Trade Area (AfCFTA) framework can be built upon to attain deeper diversification of the economy. Policies to increase tax holidays, export credits and value-chain development in commodities like cocoa, sesame, and cashew could add 3 percentage points to annual productivity growth in the country.

Among the forces explaining why productivity has been low in Nigeria, the weak pace of capital deepening seems to be the largest contributor. For instance, chronic deficits in energy and power infrastructure cost the economy between $2 and $30 billion annually, with firms self-generating high proportions of electricity need. The Nigeria Electricity Act 2023 and subsequent Siemens-powered grid upgrades aim for 10,000 MW reliable supply by 2027. This needs to be supported with accelerated integration in solar mini-grids and mini gas-to-power projects in order to fully obtain the full impact. Moreover, the 2025 Infrastructure Corporation of Nigeria (InfraCorp) seed funding of $10 billion targets roads, rail and ports. Full operationalization could reduce logistics costs from 40% to 15% of product value which will mirror infrastructure-driven productivity gains of other leading economies. One practical challenge for the public sector is to set priorities because not all needs can be met at the same time. Where fiscal space allows, governments

should fund projects especially likely to generate high social returns. In this direction, better digital infrastructure including reduced costs can amplify digital access and expose a larger proportion to the prospects of digital participation.

Human capital development must be prioritised to convert Nigeria's youth bulge into a productivity dividend. With only 36% human capital index realization (World Bank HCI 2025) and skill mismatches leaving over 50% of graduates unemployable (ILO, 2023), investments in education and vocational training are critical. The focus on expanding access needs to be shifted to improving quality in education and training. While a larger segment of the population now has a minimum of secondary education, there is still a large skill gap for driving domestic productivity in the country. Thus, there is a need to intensify skill development at all levels. For instance, scaling models like the Industrial Training Fund and NITDA's digital skills hubs to train 10 million youths by 2030 could yield substantial productivity uplifts in services and manufacturing. Health interventions that target malaria eradication and nutrition would also have further significant impacts on the workforce output. In the same vein, partnerships with the private sector for apprenticeship programs (similar to Germany's dual system) as well as diaspora knowledge transfer via the Nigerians in Diaspora Commission could accelerate skill development and ensure workers move from subsistence to skilled employment.

Policies aimed at creating a growth-friendly environment are also essential for promoting the supporting structure for tackling productivity in Nigeria. In addition to improvements in infrastructure, private sector investment constraints also need to be removed. Productivity growth can be promoted by improving the business environment, corporate governance, and the functioning of labour and product markets in the country. Lowering transaction costs and increasing trust in institutions can also improve productivity.

Moreover, governance reforms and institutional strengthening are prerequisite for sustaining productivity gains. Productivity gains can stem from policies that limit market power and promote fair competition, more even-handed contract enforcement, simplified and transparent legal systems and governance reforms that lower political risks. A useful tool for achieving better institutions is the digital economy. Digitalising procurement and other judicial reforms have improved Nigeria's Ease of Doing Business ranking modestly since 2022. However, deeper measures that influence the civil service, courts and government transactions are needed. Singapore's institutional model demonstrates how trust-building can raise TFP by up to 2% annually. In the same vein, consistent implementation of the Petroleum Industry Act and improved security in food-

producing regions could increase business confidence and help to formalise millions of informal firms.

Promoting technological adoption and innovation is also vital to leapfrog productivity bottlenecks among the sectors of the economy. With R&D at 0.26% of GDP, Nigeria lags far behind Malaysia's 1.5%, with strong implications for innovative performance of firms in the country. The National Policy on Science, Technology and Innovation 2024 targets a 1% R&D spending to GDP by 2030. In this line, tax incentives for startups, technology transfer hubs and intellectual property reforms could catalyse other governments initiatives. The mega success stories of fintech companies (contributing up to 5.8% to GDP) suggests that extending digital tools to other critical sectors like agriculture and manufacturing could boost yields and factory efficiency over time. Tertiary institutions in the country must also be fully put into active use in the drive for technological transformation. For instance, establishing innovation clusters around universities could further foster firm-level upgrading.

Within the private sector, a crucial challenge for growth and productivity has been linked to finance constraints. Thus, improving access to finance for small and growing businesses addresses the credit constraint stifling firm growth. Over 90% of Nigerian firms are micro or informal which are unable to scale due to the finance barriers imposed by collateral requirements and high interest rates. The Central Bank of Nigeria's interventions like the NIRSAL credit scheme and Development Bank of Nigeria must be expanded to target other vulnerable groups like women and youth entrepreneurs. In the modern era, innovative finance models like blended finance systems that combine government guarantees with private capital as well as more comprehensive fintech lending platforms can further deepen access to finance.

Given the critical nature of agriculture in the Nigerian economy, there is a need to modernise the sector to offer better pathways to rapid productivity gains. Agriculture employs 40% of workers, which suggests that improved productivity in the sector is a direct means of addressing poverty in the country. The 2025 special agro-industrial processing zones in Kaduna, Cross River, and Oyo states, supported by AfDB funding, target 15% to 20% productivity increases in agriculture through value addition. This will further create more decent jobs in the sector and reduce food insecurity in the country.

Finally, inclusive policies and adaptive implementation can ensure sustained impacts of productivity growth over time. This would involve gender-inclusive approaches to macroeconomic reforms. Currently, women comprise 70% of informal workers and face barriers to land and credit access. Other things equal,

reducing gender differentials in education, economic access and labour force participation would enhance the human capital available for production and management and increase the ratio of workers to population, thereby raising productivity and income. Inclusive policies also involve climate-resilient investments and adequate social protection to cushion the negative fallouts of reforms.

6. Conclusion

The challenge of low productivity in Nigeria is far-reaching in terms of its causes and implications. Therefore, the persistent productivity crisis represents both a major developmental hurdle and a defining opportunity for structural transformation. As this study documents, the nation's vast human and natural resource endowments have been stymied by structural constraints, sectoral inefficiencies and lagging innovation. These have resulted in historically low output per worker and slow poverty reduction efforts despite episodic GDP growth. Central to these challenges is a pattern of misallocated capital, weak infrastructure, skill mismatch and institutional fragility that perpetuates deep segmentations in the economy.

The findings from the study highlight that sustainable economic advancement for Nigeria must be anchored on wide-ranging productivity reforms. Real change towards tackling low productivity in the country demands coherent strategies that combine short-term stabilisation measures with long-term investments. Specifically, investment must target human capital, technological capacity and supportive institutional frameworks. Policies to broaden sectoral diversification are also vital to absorbing the expanding youth workforce into productive and higher-income employment. Thus, critical steps in the productivity drive must include upgrading of infrastructure, advancing digital penetration, scaling quality of education through skill-building, promoting inclusive policies for women and vulnerable groups and fostering pro-competitive regulatory environments that incentivize innovation and formalisation.

Ultimately, the future trajectory of aggregate productivity growth in Nigeria depends on forging a strong consensus around the productivity agenda as the foundation for shared prosperity, social inclusion and long-term economic resilience. Without substantive shifts, especially in education quality, energy supply, financial access and governance efficacy, GDP expansion will remain hollow, and millions will be at risk due to being left behind in the growth process. If Nigeria leverages its demographic dividend and harnesses technological change

it can decisively reverse the current productivity malaise, reduce poverty and chart a path toward middle-income status and regional economic leadership.

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