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| RESEARCH ARTICLE

Socio-Economic Impacts and Fiscal Vulnerabilities Following the February 6, 2023 Kahramanmaraş Earthquakes in Türkiye

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| ABSTRACT

The two major earthquakes (Mw 7.7 and Mw 7.6) that occurred on 6 February 2023, centered in Kahramanmaraş, produced profound socio-economic impacts in southeastern Türkiye. The disaster directly affected eleven provinces, caused widespread destruction, and resulted in more than 50,000 fatalities, while also leading to significant losses in Syria. Approximately 14 million people were directly affected by the physical destruction, and long-term socio-economic consequences are expected to persist. This study evaluates the direct and indirect economic losses caused by the earthquakes within a comprehensive framework, focusing on their impact on production, foreign trade, labor markets, and public finance. In this context, the Adaptive Regional Input–Output (ARIO) model, which enables time-dependent analysis of post-disaster economic impacts, is employed. The findings indicate that the earthquakes weakened regional production capacity, increased employment losses, and significantly expanded public expenditures, thereby deepening fiscal vulnerabilities. Population mobility has also led to structural changes in labor markets and national economic balances. Although reconstruction activities may support short-term recovery, sustainable growth requires integrated policy strategies that strengthen fiscal resilience, restore employment, and enhance long-term regional economic resilience and stability.

| KEYWORDS

Socio-economic impacts, fiscal resilience, ARIO model, economic vulnerability

| ARTICLE INFORMATION

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1. Introduction

Earthquakes, among natural disasters, are at the forefront of events that lead to the most devastating consequences. As the intensity of disasters increases, both the loss of life and economic imbalances deepen. In the modern era, the damage caused by natural disasters is not limited solely to the affected region; it also impacts many different countries and economies through global production and supply chains. In addition to economic losses, the social and societal dimensions of natural disasters are also extremely prominent. These risk-bearing events create serious psychological effects on individuals. In particular, earthquake victims face severe trauma due to the fear and uncertainty they experience. Beyond physical destruction, earthquakes yield social consequences that damage the societal structure and significantly reduce the quality of life (Sabırsız and Şöhret, 2024).

Due to its geographical location and tectonic conditions, Türkiye is under significant earthquake hazard. On average, the country experiences destructive earthquakes approximately every 1.5 years. On February 6, 2023, two powerful and closely timed earthquakes struck southern Türkiye, centered in the Kahramanmaraş province. Occurring at 04:17 and 13:24 local time, these events originated from distinct but nearby sources. While they rank as the second largest in the nation's history by magnitude, they stand as the most catastrophic in terms of human casualties and physical destruction. The disaster impacted 11 provinces, which account for roughly 14% of the country's landmass, and triggered massive secondary economic consequences (Işık et al., 2023a; Aydın et al., 2026).

In the 06th of February earthquakes, the devastation caused by the primary tremors and aftershocks, the resulting psychological crises, the insufficiency of resources, and various grievances occurred simultaneously. While those trapped under the rubble struggled to survive, those outside battled harsh weather conditions and inadequate means. The severity of the climate contributed to the rise in fatalities and prevented search and rescue operations from being conducted effectively, particularly during the critical first 72-hour window. Furthermore, the fact that survivors faced hunger and that aid trucks arriving from across the country encountered difficulties reaching the disaster zone points to a significant lack of coordination. Salcıoğlu et al. (2007) showed that high levels of post-traumatic stress disorder (PTSD) (40%) and comorbid depression persisted even three years after the 1999 Marmara Earthquake and revealed that the strongest predictor of PTSD was intense fear during the earthquake, and depression was especially family loss. The findings point to the long-lasting psychosocial effects of large-scale earthquakes and the need for community-based mental health interventions.

2. Scale of Damage and Economic losses

The earthquakes that occurred in Kahramanmaraş, and in Hatay on February 6, 2023, have been recorded as the greatest disaster in the history of the Republic due to the loss of life, vast area of impact, and severe destruction they caused. While these earthquakes affected over 14 million people across a region of approximately 120.000 square kilometers, 53.737 people lost their lives, 107.213 were injured, and the evacuation of more than three and a half million people from the region became necessary. Damage assessment studies conducted as of November 2024, revealed that out of a total of 2.337.455 buildings, including residential housing as well as public buildings, historical and cultural structures, educational institutions, hospitals, and commercial facilities, 39.466 had completely collapsed. Furthermore, it was determined that 21.175 buildings required urgent demolition, 199.967 were heavily damaged, 43.698 were moderately damaged, and 1.954.378 buildings were either slightly damaged or undamaged (Figure 2) (SBB, 2025). According to the post-earthquake damage assessment studies that were carried out by the Ministry of Environment, Urbanization, and Climate Change across 18 provinces, 179 districts, 8,474 neighborhoods, and 2,472 villages, the total number of residential units classified as requiring urgent demolition, completely collapsed, heavily damaged, or moderately damaged was determined to be 662,891. Additionally, 113,078 commercial units and 23,494 barns and haylofts fall within these same damage categories (SBB, 2025).

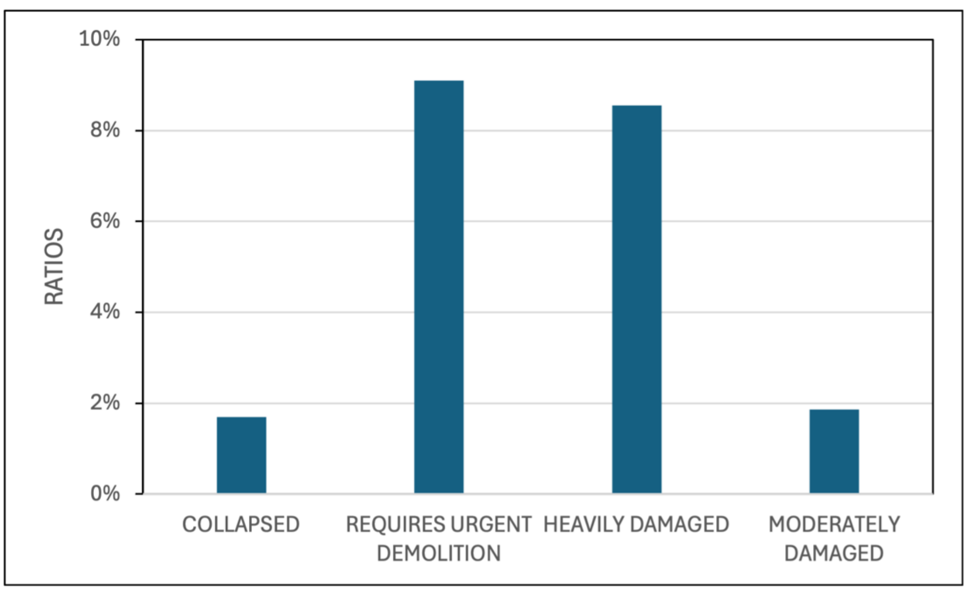

Figure 2. Building Damage Rate Caused by the 6 February 2023 Kahramanmaraş Earthquakes

The eleven damaged provinces were not affected at the same level, especially Adıyaman, Hatay, Kahramanmaraş and Malatya were the most damaged provinces. In Table 1, the number of buildings by province is given according to the AFAD / Ministry of Environment report.

Table 1. Province-based damage distribution figures

Province	Total Number of Inspected Buildings	Severely Damaged/ Collapsed	Moderate	Minor	Undamaged
Adana	7.724	59	304	1.688	5.313
Adıyaman	34.578	6.990	2.613	11.694	9.310
Diyarbakır	28.969	634	718	6.725	18.039
Elazığ	3.114	664	138	1.460	723
Gaziantep	156.482	12.964	4.361	29.471	89.092
Hatay	68.116	15.248	2.827	17.212	29.188
K.Maraş	69.577	12.980	1.058	20.556	25.420
Kilis	6.608	812	137	2.208	2.849
Malatya	32.344	8.365	945	8.960	7.463
Osmaniye	34.797	2.531	266	8.034	22.041
Şanlıurfa	39.557	466	550	13.507	19.585

2.1. Destruction and Direct Economic Loss

When the direct economic losses caused by the February 6 earthquakes are examined across a wide range, from macroeconomic balances to firm-level micro-data and public finance, it is observed that the scale of the damage corresponds to a significant portion of the national income. While estimates regarding the total cost of the earthquake to the Turkish economy vary, the consensus is that the ratio of the cost to GDP is very high. According to data from the Strategy and Budget Presidency (SBB), the total burden is approximately $103.6 billion, which corresponds to 9% of the national income. Looking at estimates from different organizations, the World Bank estimated direct damage at $34.2 billion, TÜRKONFED at $84.1 billion, and some academic projections have foreseen costs reaching up to $147 billion. Housing damage constitutes the largest item of this cost. According to SBB data, housing damage accounts for 54.9% of the total burden, amounting to approximately $56.9 billion, while damage to public infrastructure and service buildings is at the level of approximately $12.8 billion (Dürrü, 2025; Pınar et al., 2025).
Scientific studies reveal the details of direct losses in production units. According to analyses by Pınar et al. (2025) using micro-data from the Ministry of Industry and Technology's Entrepreneur Information System (EIS), it is calculated that a direct value-added loss of between $2 billion and $3.8 billion occurred as a result of physical destruction in production facilities. However, the most significant disruption in the commercial cycle of firms was seen in sales. Net sales losses are estimated to be between $13.7 billion and $23.1 billion. Based on the first damage scenario in the study, firms' loss of tangible fixed assets is approximately $1.9 billion, while stock loss is at the level of $2 billion. On a sectoral basis, the textile sector was the manufacturing sector most damaged in terms of tangible fixed assets and physical capital with $310.6 million. The trade sector took the heaviest hit in terms of turnover with a net sales loss of $4.3 billion. Kızıltoprak (2025) states that the total loss of industrial enterprises reached 155 billion TL.

Another area directly affected by the earthquake is public finance and taxation. The direct destruction created by the earthquake in the financial structure caused sharp declines in tax revenues. In February 2023, when the earthquake occurred, tax revenues across Türkiye decreased by 29% compared to the previous month. On a provincial basis, the loss is much more dramatic. In the month following the earthquake, tax revenues in Kahramanmaraş fell by 92%, and in Hatay by 48%. While the share of the 11 provinces in the region in total tax revenues stood at 5% before the earthquake, this rate decreased by half to 2.5% after the earthquake (Boz and Demirbozan, 2024).

Direct losses are also evident in energy, transport, and agricultural infrastructure. The amount of damage to electricity and natural gas facilities in the energy sector was determined to be approximately 21.7 billion TL. In the transport network, an investment of approximately 22.9 billion TL was planned to repair damage to highways and motorways. As of the end of 2024, 12.7 billion TL of this has been spent. In the agricultural sector, 17,102 barns and shelters were destroyed or severely damaged. 8,095 cattle and 69,982 small ruminants, along with more than 42,000 poultry, perished (SBB, 2025).

2.2. Impacts on Production, Industry and Foreign Trade

The 11 provinces in the earthquake zone play a critical role in industry, accounting for approximately 9.8% of Turkey's GDP and 8.6% of total exports (Ateș, 2024). The loss of human capital in production following the earthquake also holds a significant place. Loss of life, intense migration, and the difficulty of finding qualified personnel after the disaster have made it nearly impossible to maintain the workforce. As seen in the Malatya example, daily wages for manual laborers created a nearly five-fold increase in labor costs. Furthermore, employees lost their families and/or faced housing issues, which led to psychological traumas, decreasing production efficiency and quality in factories (Kahveci and Yıldız, 2025; Ketboğa, 2024).

The earthquake paralyzed the region's logistics infrastructure, creating a domino effect in the supply chain. As a result of the fire and damage at the Port of Iskenderun, ships were diverted to Mersin Port, which suddenly increased the workload in Mersin by 1.5 times. This situation imposed additional transportation, loading-unloading, and storage costs on companies, doubling customs clearance expenses. The damaged highways and the increase in the workload of vehicles led local and intercity transport prices to increase substantially, making access to raw materials more difficult (Ketboğa, 2024).

In the first 8 months of the earthquake, the total export loss of the 11 provinces was approximately $2.4 billion (Ateş, 2024; Özsalman and Yıldırım, 2024). However, as of March, exports entered a V-shaped process, demonstrating a rapid and full recovery (Ateş, 2024). A key factor in this rapid recovery was firms making contract manufacturing agreements with facilities in relatively less damaged provinces like Gaziantep and Adana to sustain production (Kahveci and Yıldız, 2025). During the same period, imports in the region contracted approximately $4.26 billion (Özsalman and Yıldırım, 2024). Unlike exports, imports did not recover at the same rate and followed a negative trend. The primary reasons for this include the decrease in consumption demand from the migrating population and the reduced demand for raw materials and intermediate goods from destroyed factories (Ateş, 2024).
When sectoral effects are analyzed, the automotive sector is one of the most affected sectors, with decreases between 60% and 80% in Adıyaman, Diyarbakır and Malatya (Özsalman and Yıldırım, 2024). The agricultural sector has been able to maintain and maintain its exports more resiliently thanks to brand loyalty to geographically indicated products such as apricots from the Malatya region (Ateş, 2024; Ketboğa, 2024). Beyond production and logistics issues, companies operating in the earthquake zone faced serious financial and commercial reputational risks. Banks refused to accept damaged factories and buildings as loan collateral; This, in turn, cut off firms' access to financing and significantly impacted investments (Ketboğa, 2024).

Beyond production and logistics issues, firms operating in the earthquake zone faced serious financial and commercial reputation risks. Banks refused to accept damaged factories and buildings as collateral for loans, which cut off firms' access to financing and significantly impacted investments (Ketboğa, 2024). The perception among international customers that delivery could not be made led to order cancellations and market loss. To overcome this crisis of confidence, firms had to prove their production capacities through various methods, such as video calls (Kahveci and Yıldız, 2025). To compensate for these losses, the state carried out approximately 2.6 trillion TL in public spending in the region during the 2023–2024 period (SBB, 2025).

2.3. Gross Domestic Product (GDP) and Growth

It is calculated that the total cost of the earthquakes to the Turkish economy is at a level of approximately 103.6 to 104 billion dollars, and this amount corresponds to approximately 9% of the national income (Işık et al., 2023b). While the share of the 11 cities in the earthquake zone within Turkey's GDP was 9.9% in 2022, it declined to 9.8% in 2023 (SBB, 2025). A loss of value-added has also occurred in the region. In analyses conducted with firm-level data, the direct loss of value-added caused by physical damage was calculated to be between 2 and 3.8 billion dollars. While this direct loss corresponds to a limited rate of approximately 1% of the national GDP, it is predicted that the total economic impact could reach up to 10% of the national income when indirect effects, such as disruptions in the supply chain, are considered (Pınar et al., 2025). In contrast, the GDP per capita in the region, which was 6,427 dollars in 2022, rose to 7,985 dollars in 2023. However, the reason for this increase is not rising prosperity, but a mathematical phenomenon resulting from the decrease in the region's population due to migration and loss of life, while the decrease in GDP was not at the same rate (SBB,2025; Kızıltoprak, 2025).

Despite expectations that the earthquake would pull down the 2023 growth rate, the Turkish economy closed the year 2023 with a growth rate of 5.1% (Işık et al., 2023a; SBB, 2025). Accordingly, emergency expenditures immediately following the earthquake, debris removal activities, humanitarian aid, and public expenditures for reconstruction stimulated economic activity in the short term, providing a positive contribution to growth in the first quarter (SBB,2025; Dürrü, 2025). However, although the earthquake created a positive effect through increased spending in the first quarter, it negatively affected growth in the second quarter due to supply constraints and production losses (Dürrü, 2025).

In the long term, the impact of post-earthquake public investment expenditures on economic growth is debated. According to one view, the growth support led by reconstruction activities is temporary. This effect will diminish as new structures are delivered (SBB, 2025). According to another finding, the diversion of public resources into unproductive areas and financing pressure may create a negative impact on economic growth in the long run (Dürrü, 2025). Furthermore, it has been suggested that in places where the extent of damage is high compared to other provinces, recovery may take a long time and there may be permanent damage (Kızıltoprak, 2025).

2.4. Job Loss and Social Impacts

The February 6 earthquakes had a tremendous effect on the labor market and caused significant ruptures in the social structure. Immediately after the earthquake, the labor market experienced a sudden collapse due to the destruction of workplaces and the loss of lives or migration of employees. According to International Labour Organization (ILO) data, a loss of working hours equivalent to the labor of 657,147 employees occurred in the earthquake zone; 220,000 workplaces in the region became unusable (Işık et al., 2023a; Kızıltoprak, 2025). Analyses based on Entrepreneur Information System (GBS) micro-data show that between 50,000 and 88,000 direct employment losses were experienced as a direct result of physical damage to production units (Pınar et al., 2025).

The impact of the earthquake on labor tends to evolve into a structural problem rather than a temporary fluctuation. Analyses by (Akarsu et al., 2025) indicate that exits from the labor market in the earthquake zone increased by 2.5 points and long-term unemployment rose by 3 points. Women, low-wage workers, and those with less experience were disproportionately affected by the losses in the labor market. The earthquake created an employment problem in both the migrant-sending and migrant-receiving provinces. While the disaster area sending migrants experienced a loss of qualified labor and a labor supply shock; receiving provinces such as Mersin and Ankara faced risks of labor supply surplus, wage pressure, and an increase in informal employment (Karagöz, 2026). Furthermore, (Ketboğa, 2024; Marangoz et al., 2025) state that the standstill of social life in the region reduced the desire of the qualified workforce to return, and this situation disrupted the recovery processes and future planning of businesses.

One of the most prominent social effects caused by the earthquake are housing problems and psychological traumas. Due to the earthquake, approximately 3.3 million people were displaced, and nearly 2 million people were evacuated from the region by reporting to official authorities. The housing problem paralyzed social life and created a serious sense of loss of security and belonging among survivors. Sleep disorders, depression, and post-traumatic stress disorders are reported to have become widespread among earthquake victims. Long-term psychological effects have been observed particularly in youth and children [Marangoz and İzci, 2023; Marangoz et al., 2023). The earthquake also adversely affected educational life in the region. More than 7.1 million students and over 20,000 educational institutions in the earthquake zone were affected, and educational activities were interrupted. Additionally, the deterioration of hygienic conditions and problems accessing clean water increased the risk of epidemics (Sabırsız and Şöhret, 2024).

In the long term, the demographic structure of the region is expected to change, and poverty is expected to deepen. The fact that the socio-economic development levels of the provinces affected by the earthquake are below the Turkish average indicates that the disaster will have an effect that increases poverty and income inequality (Sabırsız and Şöhret, 2024). The collapse of micro-enterprises in the region and the decrease in the number of workplaces have weakened the income-generating capacity of the local economy in the long term. Moreover, due to the collapse of care services and the increase in household burden, the risk of women permanently withdrawing from employment is high (Karagöz, 2026).

2.5. Demographics and Migration

The February 6 Kahramanmaraş earthquakes not only shook the existing population structure across the 11 affected provinces but also triggered one of the largest mass migration movements in Turkish history. The population structure and demographic characteristics of the region already possessed features that differed from the Turkish average prior to the earthquake. The total population of the 11 provinces directly affected by the earthquake was approximately 14 million at the end of 2022. This figure accounted for 16.4% of the national population (SBB,2025; Ateş, 2024). Following the earthquake, this share regressed to 16.2% in

2023 and showed a slight increase to 16.25% in 2024 (SBB, 2025) (Günay and Ipek, 2025). The region has a younger population structure than the Turkish general average. According to 2023 data, 20.9% of the population in the region consists of the 0-17 age child group, while 16.4% is in the 18-29 age youth group. The share of the working-age population between 15-64 is around 68% (SBB, 2025). The average household size in the region is 3.7 people, which is above the Turkish average of 3.2. Furthermore, approximately 1.3 million people—representing 46% of Syrians under temporary protection in Türkiye—reside in these 11 provinces affected by the earthquake (SBB, 2025).

Between 2.7 million and 3.3 million people were displaced following the earthquake (Karagöz, 2026; Marangoz and İzci, 2023; Marangoz et al., 2025). The number of people evacuated solely through official authorities is close to 2 million (Marangoz and İzci, 2023). Some estimates based on GSM signals have also indicated that the number of people leaving the region approached 3 million. Increases in waste management volumes in certain cities also corroborate this massive population mobility. Three trends emerged in post-earthquake migration movements. First was the migration to rural areas for security purposes. This form of migration was observed to be temporary. Secondly, earthquake victims migrated to nearby or neighboring provinces that were not damaged. The reasons for earthquake victims migrating primarily to the provinces of Mersin, Diyarbakır and Antalya include kinship ties and employment opportunities in these cities. Finally, long-distance migrations were counted among the post-earthquake migration trends. Migrations of this nature generally headed toward large cities distant from the earthquake zone, such as Ankara, Istanbul, and Izmir, and the likelihood of those migrating to return was assessed as weak (Aslan, 2023).

Post-earthquake population movements were also felt as labor loss and employment contraction. According to March 2023 data, the number of registered salaried employees in the earthquake zone decreased by 23.6% compared to the previous year. The number of jobs in the region declined by 30.2%. Labor loss reached 51.1% in Kahramanmaraş, 49% in Hatay, and 41.3% in Malatya. In Adıyaman, Hatay, Malatya, and Kahramanmaraş, the decrease in the number of workplaces is over 50%. The female workforce experienced a sharper contraction compared to men. For example, female employment in Hatay decreased by more than 70%. The skilled labor leaving the region has created a serious risk of brain drain and increased labor costs in the industrial and social service sectors (TEPAV, 2023).

2.6. Reconstruction and Public Expenditures

The reconstruction activities and public expenditures carried out following the February 6 earthquakes have created a significant fiscal burden on the Turkish economy, with total public spending reaching approximately 2.6 trillion TL (roughly $75 billion) during the 2023-2024 period (SBB,2025; Dürrü, 2025). These expenditures can be analyzed under three main areas: emergency response, permanent infrastructure investments, and social support.

Immediately after the earthquake, public finances focused on search and rescue operations and meeting urgent humanitarian needs. Cash transfers were carried out, such as a 10,000 TL support payment per household, relocation assistance (15,000 TL), and aid to the relatives of those who lost their lives (100,000 TL) (SBB,2025). Following the tent cities, 650,000 disaster victims are being sheltered in approximately 214,000 containers across 395 established container cities. Additionally, a total of 34.5 billion TL in rent support has been provided to 362,739 households meeting their housing needs through their own means (SBB, 2025).

The largest portion of public expenditures consists of the reconstruction of damaged cities and the renewal of infrastructure. Out of a total of 391,245 housing beneficiaries, residences have been delivered to 201,431 individuals whose lottery process has been completed. Furthermore, under the "On-Site Transformation Project," citizens are offered 750,000 TL in grants and 750,000 TL in credit support for housing (SBB, 2025). 24.1 billion TL was spent on the construction of 7,497 classrooms in education, while 4.5 billion TL was spent on maintenance and repairs. In the field of health, 35.2 billion TL in resources has been allocated for the construction/repair of hospitals and health facilities for the year 2025 (SBB,2025). In transportation, as of the end of 2024, 12.7 billion TL has been spent to repair damage to highways and motorways, and 18.6 billion TL for railways. In energy infrastructure, approximately 18.8 billion TL was spent on repairing damage to electricity and natural gas (SBB, 2025). For water and sewerage infrastructure, external financing totaling 81.5 billion TL was provided in addition to İLBANK and DSİ projects (SBB, 2025).
To revive the regional economy and maintain social balance, various incentives for the labor market, agriculture, and businesses have been implemented. 111,000 people benefited from the short-term work allowance and 82,000 people from the cash wage support. In this context, approximately 2 billion TL (at 2025 prices) in payments were made. 20 billion TL in support was provided to 60,673 businesses through KOSGEB (SBB,2025). In 2024, 20.9 billion TL in agricultural support payments were made to producers in the region, and in-kind livestock distribution and compensation payments were carried out for perished animals (SBB, 2025). To finance these expenditures, 30.1 billion TL in additional income was generated in 2023 through regulations such as the Additional

Motor Vehicle Tax (MTV), and increases were made to Corporate Tax and VAT rates. Tax debts and declaration periods for taxpayers in the earthquake zone have been postponed under the scope of force majeure (Boz and Demirbozan, 2024).

3. Aim of the study

This study offers a novel contribution to the disaster risk reduction literature by providing an integrated and up-to-date socio-economic assessment of the February 6, 2023, Kahramanmaraş earthquakes, one of the most destructive seismic events in recent history. Unlike existing studies that predominantly focus on either physical damage assessment or short-term macroeconomic effects, this research systematically combines regional production losses, labour market disruptions, dynamic migration, public finance impacts, and supply-chain effects within a single analytical framework. It aims to model the regional economic impacts, direct and indirect economic losses, inter-sectoral supply chain disruptions and adaptation processes of the 7.8 and 7.6 Mw earthquakes that occurred in Kahramanmaraş and its surroundings. By synthesizing newly released post-disaster data (2024–2025) from official institutions and recent empirical studies, the paper captures the medium-term structural consequences of the disaster that have largely been overlooked in earlier analyses. The study further advances the literature by translating these findings into concrete, resilience-oriented policy implications, thereby linking socio-economic impact assessment directly to disaster risk reduction and recovery planning. In this respect, the paper goes beyond descriptive damage analysis and contributes policy-relevant evidence on how large-scale disasters reshape economic structures and regional resilience in emerging economies.

Within the scope of the study, adaptive regional input-output (ARIO) model was used. This model, which is especially effective in estimating chain economic losses after disasters, has been successfully applied by different researchers in estimating economic losses after disasters in recent years. Issa et al. (2025) analyzed the temporal uncertainties of economic and housing recovery through the example of the 2016 Kumamoto Earthquake, presenting a refined ARIO approach that considers dynamic reconstruction rates, sector-based behavioral parameters, and housing losses separately from production capital in order to assess indirect economic losses more realistically. Through the example of the July 2021 flood disaster in Germany, it was shown that the results of the ARIO model are highly sensitive to data sources and key parameter selections, and it was revealed that different scenarios, recovery dynamics, and various multi-regional input-output tables should be evaluated together in order to obtain reliable results in indirect economic loss analysis (Juhel et al., 2024). Wu et al. (2012) use the ARIO model for the 2008 Wenchuan Earthquake to show that indirect economic losses reached approximately 40% of direct losses (CNY ≈300 billion) and economic recovery took about 8 years, demonstrating that strong public support policies play a critical role in mitigating post-disaster economic impacts.

4. Methodology

The economy is made up of interconnected sectors. Damage in one sector spreads to other sectors in chains. This effect is called indirect economic losses. Adaptive Regional Input–Output Model (ARIO) method is a dynamic economic model used to analyze how economic losses spread over time after disasters (especially earthquakes, floods, hurricanes, etc.) and how the economy recovers. It is an improved version of classical input-output (IO) analysis and adapted to disaster economics. The ARIO model is a dynamic regional economic simulation model that calculates losses in production capacity, cross-sectoral dependencies, supply chain disruptions, reconstruction process, temporal evolution of economic recovery after a disaster. The model was first developed by Hallegatte (2008). Classical Input–Output models illustrate the economic relationships across sectors. However, it does not have a time dimension, does not include production capacity constraints, and cannot model post-disaster adaptation. In reality, after the earthquake, factories are damaged, labor is reduced, the supply chain is broken, companies switch to alternative production, and there is a demand for reconstruction. The ARIO model represents exactly this adaptive behavior. The ARIO model has been used only to a limited extent in Türkiye. One of the main reasons for this is the limited availability of regional input–output tables. In addition, the high data requirements and the fact that disaster economics is a relatively new and developing field have limited researchers' interest in this topic. Further development in this field requires interdisciplinary expertise.

4.1. Theoretical Framework of the ARIO Model

The ARIO model adapts the classical input-output approach to disaster conditions, considering the change in production capacity over time. Basic production constraint is given with formula (1):

$$x_i(t) \leq \min\{D_i(t), C_i(t)\} \quad (1)$$

Where

$x_i(t)$: Production of sector I at time t

$D_i(t)$: industry demand

$C_i(t)$: Post-disaster production capacity

Post-disaster capacity can be calculated formula (2):

$$C_i(t) = K_i(t) \cdot \alpha_i \quad (2)$$

4.2. Main Components of the ARIO Model

Intersectoral flow in the economy is given by formula (3)

$$X=AX+Y \quad (3)$$

Where

X : total production
A : technical coefficient matrix
Y : nihai talep

Following the disaster, production capacity decreases and part of the capital stock is lost. As a result, the remaining capital stock operates under the constraints created by disaster-related damage. This can be illustrated by formula (4),

$$K_i(t) = K_{i0} - Damage_i(t) \quad (4)$$

Where,
K_{i0} : Initial Capital
$K_i(t)$: Remaining Capital at time t

Even if there is demand after the disaster, production can be made below capacity. In this case, the adaptation period comes into play, alternative suppliers are found, stocks are used, and production is tried to be revived. In the ARIO model, this process is represented by substitution flexibility, inventory buffers and production prioritization. On the other hand, there are demands for housing construction, infrastructure and machinery renewal in the construction sector. This situation creates temporary growth in some sectors, especially construction. Under normal circumstances, expected demand increases with reconstruction demands (Formula 5)

$$Ytotal=Ynormal+Yreconstruction \quad (5)$$

ARIO works with time steps. ***t0***(Earthquake)→***t1***(Production decline) →***t2***(Supply Chain Disruption)→***t3***(Rebuilding)→***t4***(Recovery). At each time step, the economy is recalculated. The types of economic losses calculated are direct losses such as buildings, infrastructure and indirect losses such as supply chain breakage, production delay, and export decline. The ARIO method contributes more to this context. On the other hand, the recovery period, that is, the time for the economy to return to its previous production level, is revealed in the ARIO model.

The ARIO model is considered a highly advantageous method due to its ability to perform time-dependent analyses, represent realistic economic behavior, capture supply-chain impacts, conduct policy-scenario testing, and support regional analysis. However, the model also has several limitations: it requires extensive data, parameter calibration is challenging, behavioral economic responses cannot be fully represented, and uncertainty increases in small-scale economies.

5. Results

The Mw 7.8 and Mw 7.6 magnitude Kahramanmaraş earthquakes that occurred on February 6, 2023, caused serious physical and economic losses in a wide geography in southeastern Turkey. It is known that post-disaster economic effects are not limited to direct physical damage but also create indirect losses that grow over time due to supply chain disruptions and production capacity losses. In this study, the Adaptive Regional Input-Output (ARIO) model was applied to evaluate the post-disaster economic recovery process. The model has been applied for the simplified regional economy representing four main sectors: construction, manufacturing industry, services and agriculture. Initial economic sizes before the earthquakes are normalized values derived from Türkiye's regional economic distributions (Table 2).

Table 2. Pre-earthquake capital stock

Industry	Capital Stock (Billion TL)
Construction	120
Manufacturing	300
Service	400
Agriculture	80

5.1. Earthquake Damage Scenario

In line with official damage estimates and field observations, the following physical loss rates have been adopted (Table 3, Table 4 and Table 5).

Table 3. Physical loss rates

Industry	Capital Stock (Billion TL)
Construction	35%
Manufacturing	25%
Service	20%
Agriculture	15%

Table 4. Post-Earthquake Capital Capacity Calculation

Industry	Damage	Kt
Construction	**42**	**78**
Manufacturing	**75**	**225**
Service	80	320
Agriculture	12	68

Table 5. Post-Disaster Production Capacity

Industry	Initial	Kt	Capacity Loss
Construction	120	78	35%
Manufacturing	300	225	25%
Service	400	320	20%
Agriculture	80	68	15%

In the first stage, the total economic capacity decreased from 900 billion TL to 691 billion TL and a 23% loss occurred in the total production capacity.

5.2. Calculation of Indirect Economic Losses

A decrease in production due to input-output dependencies creates a knock-on effect:
- Demand for services decreases → manufacturing decline
- Agricultural supply decreases → logistics disruptions
- Construction damage → reconstruction creates demand shock

The production update for the ARIO model is calculated according to Formula (6) and given in Table 6.

$$x(t+1) = \min\left(Ax(t) + f(t), C(t)\right) \tag{6}$$

Where,
A: technical coefficient matrix
$f(t)$: final request

Table 6. Production update by ARIO Model

Time	Total Production (Billion TL)
Before the earthquake	900
First month	650
Sixth month	720
Twelfth month	810
Twentyfourth month	870

6. Discussion and Conclusions

The socio-economic effects of the February 6, 2023, Kahramanmaraş earthquakes show that large-scale natural disasters not only cause short-term physical destruction. it also shows that it creates long-term structural deterioration on economic activities, labor markets, public finances and regional development. The findings of this study reveal important policy implications, especially for developing and high-disaster risk economies such as Türkiye. First, disaster response policies should go beyond short-term emergency expenditures and include medium-long term economic recovery strategies. While post-earthquake public spending and reconstruction activities may have supported economic growth in the short term, the findings suggest that these growth effects are temporary and may exert downward pressure on long-term productivity if investments are not directed towards productive sectors. Therefore, reconstruction policies should not focus solely on housing production; It should prioritize investments that will increase regional productivity such as industrial zones, logistics infrastructure and technology-oriented production facilities. Secondly, the effects of earthquakes on the labor market reveal that employment losses and migration movements towards the labor force have turned into structural problems rather than temporary shocks. This numerical application shows that the February 6 earthquakes had not only physical but also systematic economic effects. The ARIO model is a powerful tool that can simulate post-earthquake economic recovery over time and can be used as a decision support system in earthquake-resistant urban planning studies. From the perspective of disaster-resilient urban planning, the necessity of spatial diversification of critical production centers emerges. The clustering of industrial investments in certain regions increases economic fragility. Infrastructure resilience is one of the key factors that directly affect economic recovery time. On the other hand, reconstruction investments create an economic multiplier effect.

The ARIO model results revealed within the scope of this study showed that indirect losses reached 1.4≈ times the direct loss. The resulting primordial economic shock is greater than the physical damage. The construction sector is the main driver of the recovery. The speed of recovery is determined by the dependency in the supply chain. ARIO analysis

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