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The Impact of Deterministic Relationships in Terms of Resilience and Security of the Housing Service Infrastructure

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Abstract: The housing service sector is an important component of our society and an essential sector of the human that provides critical services. The housing service infrastructure and infrastructure serves as the cornerstone of societal systems, security, economic activity, individuals and households, local government management, and economic safety. The lack of capital investment or loss of the housing service infrastructures can cause billions of dollars of economic impacts across critical infrastructures. The economic perturbations in the housing service sector will lead to the inoperability of interrelated infrastructures and sectors. The main aim of this study is to define deterministic relationships between various infrastructures within an economic system to strengthen the security and resilience of the housing service infrastructure. This study conducts economic impact analysis which is the process of predicting the outcomes of a project using historical economic data. In the event of a loss of housing services infrastructure or housing-reliant sectors, identifying the critical infrastructure or economic sectors most affected will help minimize economic perturbations and related property damage. Moreover, the crisis management ability built into the housing service infrastructure will also help in a situation where the capital investment of the housing service infrastructure is lacking or lost.

Keywords: Housing Service Sector, Interdependency, Interconnectedness, Economic Impact, Deterministic Relationships, Housing Service Infrastructure

1. Introduction

The housing services sector is a key and essential infrastructure for working our social system properly. The housing services sector involves essential and critical systems that support the principal functions of government, corporations, and households. It also forms a significant infrastructure of our social system by providing services and goods for national and economic safety, government operations, and multiple businesses. Hence, if some parts of the housing service infrastructure fail or the capital investments of the housing service infrastructures are lacking, it may cause devastating economic impacts on critical and essential infrastructures [1, 2]. These destroyed infrastructures can cause interrelated infrastructures to become inoperable, and furthermore, it can lead to the denormalization of social and economic systems [5, 6]. Therefore, to manage the housing service infrastructure in an efficient manner, strengthening the security and resilience of the housing service sector is of utmost significance. Furthermore, improving the resiliency of the housing service infrastructure will help in speeding the recovery from or resistance to adversely exogenous factors. Disruptions and fluctuations in the housing service sector from unpredictable external factors will lead to economic perturbation and related property damage, adversely affecting finance, environment, administration, business, and correlation systems [3, 4, 9]. In other words, the perturbations and disruptions in the housing service sector can have enormous societal impacts and devastating economic losses owing to the value of interconnectedness and interdependency.

The systematic and stable management of the housing service sector is contingent upon several factors:

(a) Since the housing service infrastructure cannot be

perpetual and permanent, it should be constantly matched the supply of the housing service infrastructure with the demand for the housing service infrastructure in terms of management and planning.

(b) The well-organized planning built into the housing services infrastructure is able to be in place to ensure that the housing services as a whole do not collapse. This helps ensure that the housing service continues to be provided even in times of crisis and minimizes loss and damage when some parts of the housing service sector fail.

(c) The housing service infrastructure requires immediate recovery or resistance planning from adverse exogenous factors. This can play an essential role in the well-prepared high resiliency of the housing service infrastructure.

When the housing service infrastructure is disrupted due to unpredictable exogenous factors, economic perturbations and fluctuations occur in the housing-reliant sectors and related economic sectors. The inoperability of related economic sectors and the housing service infrastructure caused by adverse external factors can significantly impact the diverse network of relationships constituting a coherent whole between economic sectors and industries. In other words, this disruption decreases the ability of housing services, and the damaged infrastructure affects the housing-reliant infrastructure systems, leading to perturbations of numerous infrastructure systems over time. Then, other economic sectors of economic and societal systems will also be affected by the value of interdependence of the housing-reliant infrastructure sectors [7, 13-15].

2. Background Research

2.1. Problem Statement and Needs

There is no effective and systematic assessment framework to estimate the cascading economic impacts of the housing service sector. The common methodology for assessing the economic impacts of the housing service sector lacks efficient methods and mechanisms. A new framework is required to measure the cascading economic impacts due to unpredictable external factors as well as the benefit and cost of strategic investments in the housing service sector to mitigate adversely exogenous impacts. Generally speaking, an economic system consists of several sub-economic systems that are interconnected and interdependent with each other. Unpredictable external factors in the housing service sector can affect economic perturbations and related property damage in the housing-reliant sectors, leading to the inoperability of related economic sectors and the housing service infrastructure [8, 10-12]. Therefore, this study attempts to suggest a novel mechanism and new framework for estimating the cascading economic impacts of the housing service sector, as shown in the following figures.

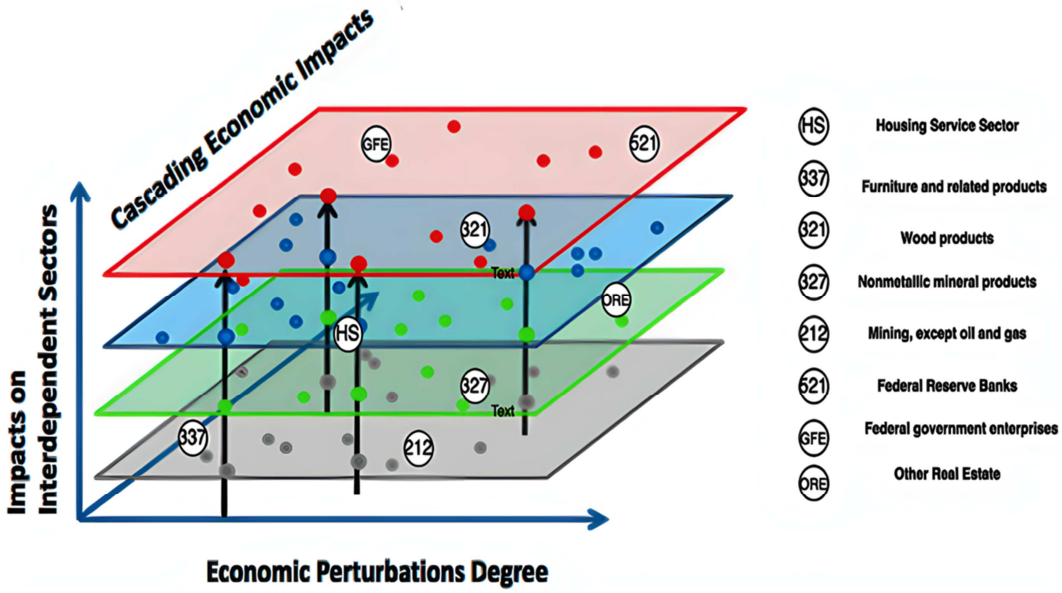


Figure 1. *Networks and Mechanisms for Estimating the Cascading Economic Impacts of the Housing Service Sector.*

2.2. What Interconnectedness of Housing Service Sector Are Saying

The loss of the housing service sector or additional capital investment in the housing service sector may financially affect our society, natural gas sector, telecom sector, water sector, transportation, electric power sector, administrative and support services, and so on. In other words, the loss of the housing service sector or efficient capital investment in the housing service infrastructure can have a negative or affirmative financial impact and societal influence. The loss or the additional capital investment caused by the financial impact of the housing service sector will greatly affect one or more economic systems. Figure 2 shows the interconnected

sectors associated with critical infrastructures, such as water, transportation, oil, natural gas, electric power, telecom, and so on. If there is additional capital investment or a lack of financial investment in the housing service sector, it will gradually affect economic impacts on one or more sectors. A direct economic impact of the housing service sectors would be the direct change of productions and needs due to additional capital investment or a tangible lack of financial investment for the housing service infrastructure. Then, an indirect economic impact on the housing service sectors would be the change in other infrastructures suffer due to due to additional capital investment or a tangible lack of financial investment for the housing service infrastructure based on the infrastructure relationships.

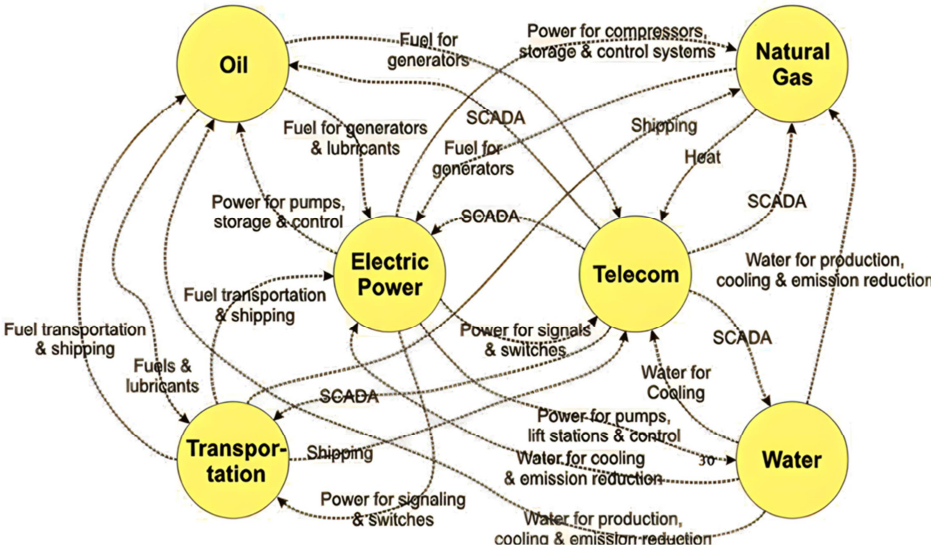


Figure 2. *Interconnected Economic Sectors Based on Critical Infrastructure Relationships (Rinaldi et al. 2001).*

2.3. Scope of Research

This study focuses on predicting economic ripple effects depending on the value of interdependence of the HS sector owing to exogenous impacts. This research utilizes the input-output accounts from the Bureau of Economic Analysis that represents industrial-economic interconnectedness across all other economic sectors in the United States economic system. The historical input-output data of the supply and demand matrices for the past twenty years are utilized to evaluate the cascading economic impacts of the housing service infrastructure. This research can be a study to consider two situations in the housing service sector. First, this study can conduct the relevant property damage and potential risks assessment of the cascading economic impacts caused by adversely external components. This can help prioritize the recovery actions of economic sectors from unpredictable external factors, making the HS sector more resilient. Second, this research can conduct the economic impact assessment caused by the financial and capital investment in the HS sector to manage appropriate and efficient investment strategies in the housing service sector.

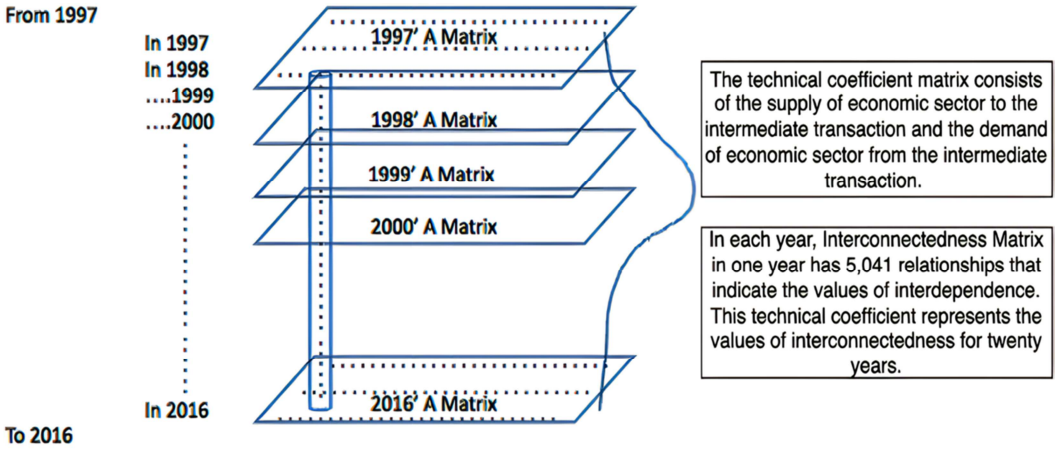


Figure 3. *The Scope of the Research Associated with the Interconnectedness Matrix for 20 years.*

Figure 3 shows the scope of the research associated with the interconnectedness matrix for 20 years. It has been defined as the values of interconnectedness across 71 economic sectors from 1997 to 2016. The technical coefficient matrix in this

research is a year-based analysis regarding associated sectors of the U.S. economic system. The interconnectedness matrix in one year has 5,041 interconnected relationships that indicate the values of interconnectedness in interrelated economic sectors, respectively.

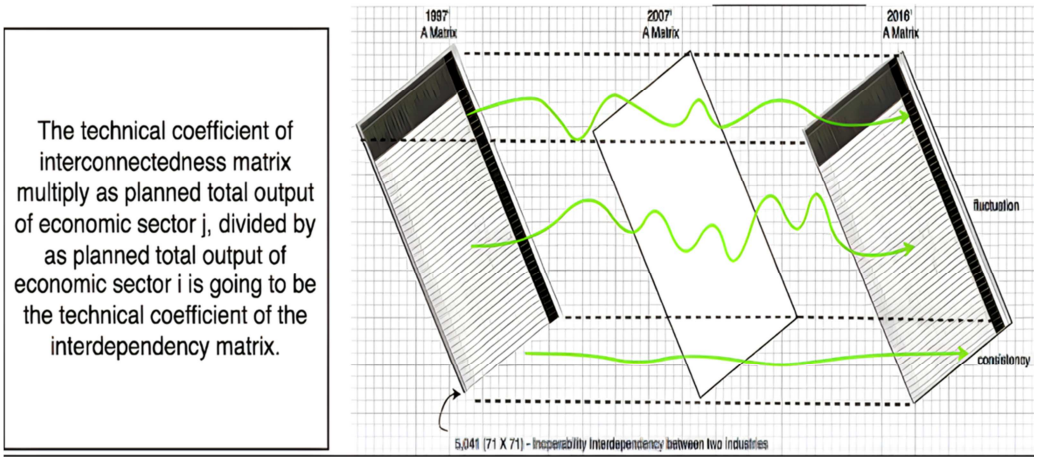


Figure 4. *The Scope of the Research Concerning the Interdependency Matrix from 1997 to 2016.*

Figure 4 shows the scope of the research concerning the interdependency matrix from 1997 to 2016. In order to measure the cascading economic impacts of additional capital investment in the housing service sector from the housing-reliant sectors to all other sectors, the interdependency matrix for the cascading impact comes from the vector of the as-planned productions of related industry and the technical coefficient matrix.

3. Method Used

In the 1750s, the model's earliest documented beginnings were the Tableau Economique which Francois Quesnay published. Decades later, Leon Walras tried to develop a general equilibrium model for solving interdependent systems' supply and demand conditions. In 1936, Wassily Leontief made the conceptual framework for the input-output structure of the economic model, and he was taken into account the value of interconnectedness and interdependence across diverse economic sectors. Wassily Leontief's framework was based on the economic input-output model from the beginning of the theoretical framework [16-17, 20-22, 25]. By analyzing these previous studies, this research tried to develop a model to measure the values of interconnectedness and interdependence using the process of tracking expenditures and sales through an economic system from the Bureau of Economic Analysis.

The following considerations concerning economic perturbations in the housing service infrastructure must be considered: (i) cascading the economic impacts on the interrelated industries due to the loss propagations of the housing service sector or additional capital investment in the housing service sector, and (ii) how unpredictable external factors of the housing service sector cause economic impacts on other infrastructures. In other words, all other economic sectors or infrastructures will also be affected by this economic perturbation in the housing service infrastructure owing to the technical coefficient matrix and interdependency matrix between the housing-reliant sectors and all other sectors.

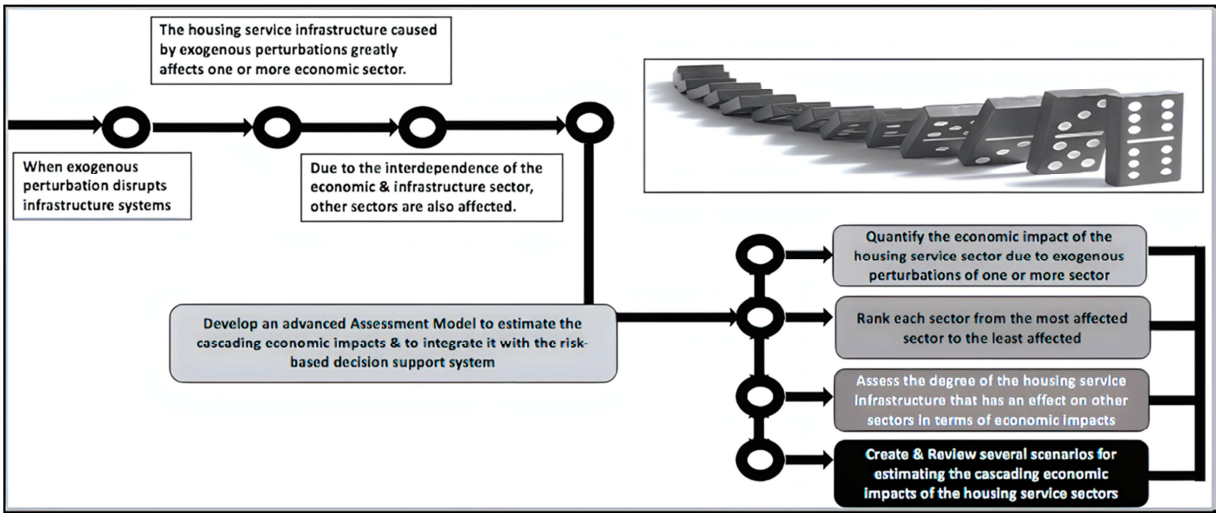


Figure 5. *Overall Research Procedure.*

Figure 5 shows the overall research procedure. The overall procedure of this study is as follows; (a) When exogenous perturbation disrupts infrastructure systems, (b) The housing service infrastructure caused by exogenous perturbations greatly affects one or more economic sectors, (c) Other economic sectors are also affected by the value of interdependence, depending on the interdependence of the infrastructure and economic sectors, (d) Develop an advanced Assessment Model to estimate the cascading economic impacts & to integrate it with the risk-based decision support system, (e) Quantify the economic impact of the HS sector due to exogenous perturbations of one or more sector, (f) the economic impact of the HS sector is identified by the ranks of each economic sector from the most affected economic sector to the least affected, (g) Assess the degree of the housing service infrastructure that has an effect on other sectors in terms of economic impacts, (h) Create & Review several scenarios for estimating the cascading economic impacts of the housing service sectors.

To measure the cascading economic impacts, it should evaluate the loss of the housing service sector from adversely exogenous factors or additional capital investment in the HS sector. Figure 6 shows the objectives that are able to be expressed as numerical and quantity values of this research.

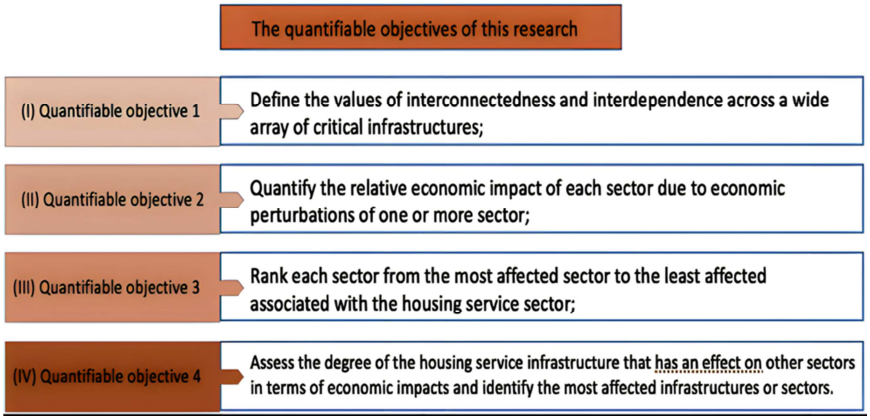


Figure 6. *Quantifiable Objectives of This Research.*

There are the methods used in the research as follows. First, the U.S. economic system in terms of the HS sector has been defined as the interconnectedness matrix, and patterns, trends, and relationships have been analyzed. Second, the cascading economic impact of internal and external changes or fluctuations in the HS sector has been analyzed. Third, it has been defined as an interdependent matrix for analyzing patterns, trends, and relationships based on such fluctuations. By doing so, it could rank each economic sector from the most affected economic sector to the least affected. It is assumed that each sector of the economy produces an equal total output over a certain period of time. Then, the technical coefficient of the interconnectedness matrix is defined for the correlation coefficients among economic sectors under that assumption [18, 19, 23, 24]. The technical coefficient of the interdependency matrix is defined for measuring cascading economic impacts of the housing service sector by considering as planned total outputs of each sector. The assumptions used in this research have several main factors as follows; (a) The data used in this research is based on U.S. Bureau of Economic Analysis demand and supply assumptions; (b) A static equilibrium-competitive economy is assumed and the economic system has constant coefficients for a fixed unit of time; (c) The resources required to produce any commodity and the inputs to other goods are proportional to the output of that commodity; (d) The U. S. economic system is assumed to consist of a group n interacting economic sectors. Each economic sector is able to add some value in dollars to interacting with other economic sectors as well as incomparable imports, rest of the world adjustment, secondhand goods, and so on.

There are components and structures of the matrices in this research as follows. The supply matrix is a commodities-produced-by-industries matrix. The elements in the supply matrix are Commodities produced by economic sectors from the intermediate transaction, Supply of values produced by the economic sectors to the intermediate transaction, Total Industry Output (X), Total Commodity Input (Y^T), Transaction Matrix (V), Noncomparable Imports and rest-of-the world adjustment, Scrap, used and secondhand goods.

(a) Noncomparable imports are commodity imports used by industry and domestic final demand but do not correspond with existing SIC commodities produced in the United States. Standard Industrial Classification.

(b) Rest of the world adjustment is an adjustment, to exports, to household consumption, and to government expenditures, for expenditures by foreigners while in the United States. There is no value-added or output associated with this sector.

(c) Secondhand goods is a special sector that accounts for the investment component of final demand selling such goods to industry, households, government, and as exports.

The elements in the demand matrix in detail are Purchases in economic sectors from intermediate demand, Supply of commodities to intermediate demand, Total Commodity

Output (Y), Total Industry Input (X^T), Noncomparable Imports and rest-of-the world adjustment, Exogenous Commodity Demand (e), Scrap, used and secondhand goods, Value added (Z).

In addition, the demand matrix has other components, such as 'value added'. The value added indicates the number of inputs other than commodities. The inputs of the 'value added' in detail are Compensation of employees (Value added 1), Taxes on production and imports, less subsidies (Value added 2), and Gross operating surplus (Value added 3).

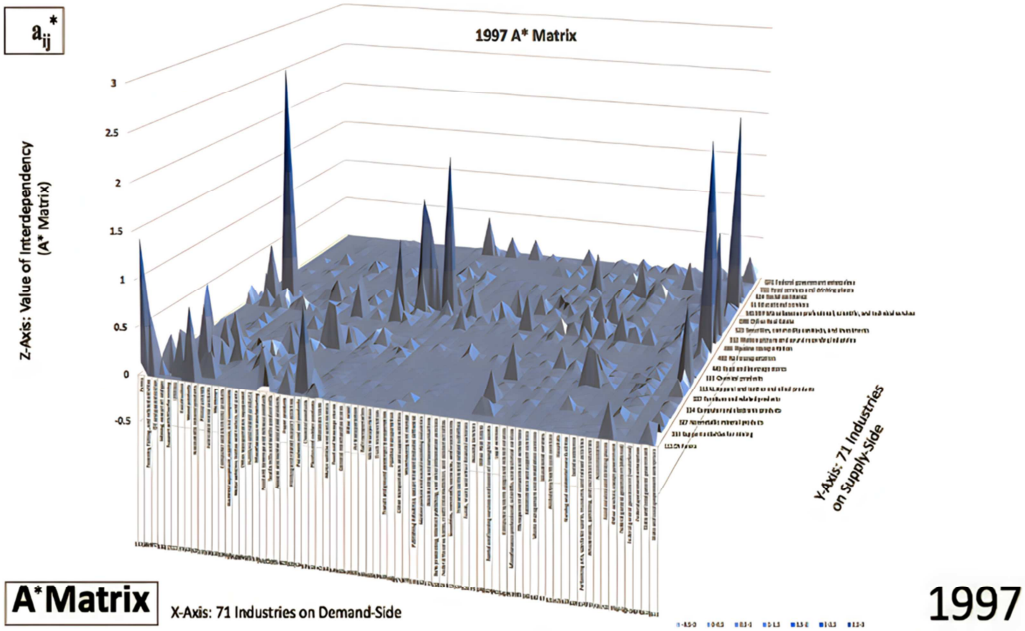
The Interconnectedness matrix is economic sectors-by-economic sectors matrix. One of the components in the interconnectedness matrix indicates the proportion of column economic sector output that is intermediate consumption of row economic sector. The components in the interconnectedness matrix are as follows.

1. Supply of economic sectors to the intermediate transaction.
2. Demand of economic sectors from the intermediate transaction.

4. Method Used Trends, Patterns, and Relationships of Interdependency Matrix

Figure 7 shows trends, patterns, and relationships of the interdependency matrix from 1997 to 2016. The Y-axis indicates the seventy-one economic sectors on the supply-side of the U.S. economic system. The X-axis indicates the seventy-one economic sectors on the demand side of the U.S. economic system. The Z-axis indicates the values of interdependency associated with deterministic relationships among the seventy-one economic sectors in the U.S. economic system. It can be interpreted that the overall patterns and trends in the value of interdependence have been somewhat fluctuant rather than a dramatic change.

The highest points in the interdependency matrix were the relationships between the pipeline transportation sector and the utility sector for the past twenty years. Except for the years 2000 to 2002 and the years 2008 to 2011, the values of interdependency represent some fluctuations in the relationships of the individual economic sector. In other words, the interdependence values do not appear to reflect radical changes overall for the past two decades. As seen in 3-D graphs, there were two times of big fluctuations in the past twenty years. There were once between 2000 and 2002 and once between 2008 and 2011. There was 'the Year 2000 problem' that was also known as the Y2K problem or the Millennium bug between 2000 and 2002 and the 'global financial crisis (GFC)' between 2008 and 2011. It could be known that these two events were consistent with the two large fluctuations in the outcomes of the 3-D graph.



Note: X-Axis represents seventy one economic sectors on demand-side.
Y-Axis represents seventy one economic sectors on supply-side.
Z-Axis represents the values of interdependency.

a) These graphs are intended to analyze patterns and trends in the values of interdependence over the past twenty years.

Relevant figures and detailed values related to the results of the study can be found in the following sections.

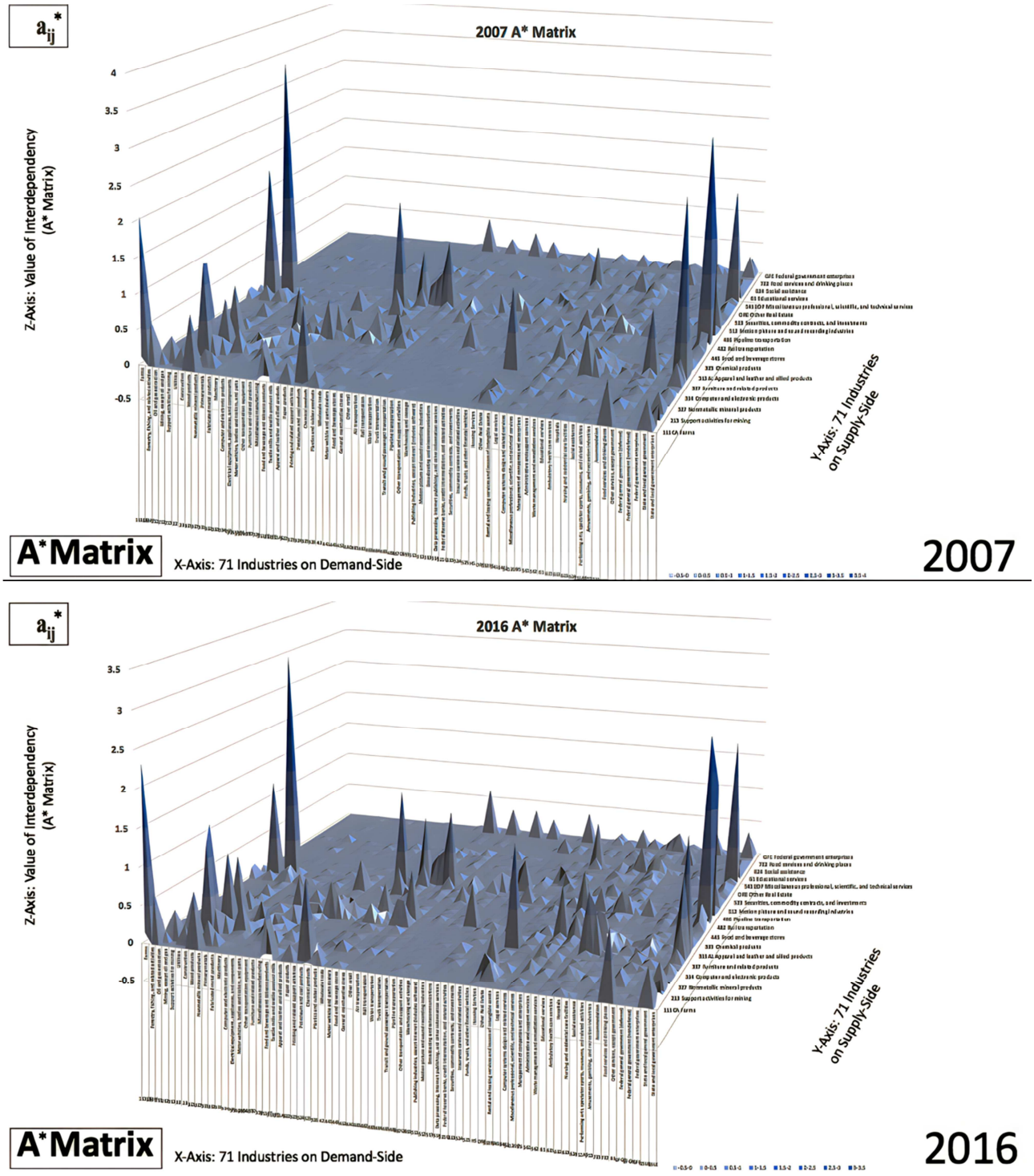


Figure 7. *Trends, Patterns, and Relationships of Interdependency Matrix.*

5. Values of Interdependence and Ranks Most Closely Associated with the HS Sector in 1997

The following sections are the results derived from the model developed in this research. Also, the following outcomes of the research came from a work dealing with the interdependency matrix to assess the correlations among diverse economic sectors and infrastructures within the U.S. economic system. The study has tried to understand how the housing service sector changed within the economic system through the ranking most closely related to the housing service sector with a gap of ten years each. In 1997, it could be found that the housing services sector and other economic sectors with a value of interdependence of 0.1 or higher were only the top five economic sectors out of seventy-one sectors. Figure 8

shows 1997' values of interdependence in terms of Housing Service sector.

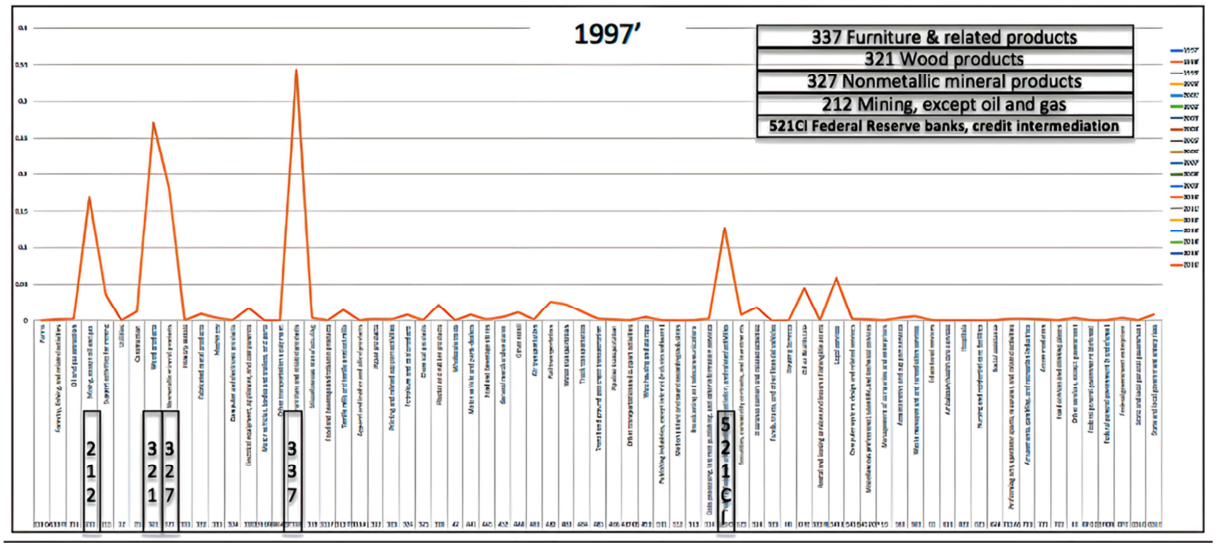


Figure 8. *1997' Values of Interdependence in terms of HS sector.*

The ranks most closely associated with the HS sector in 1997 are included as follows: <1> the furniture and related products industry (IOcode: 337); <2> the wood products industry (IOcode: 321); <3> the nonmetallic mineral products industry (IOcode: 327); <4> the mining, except oil and gas (IOcode: 212); <5> the federal reserve banks, credit intermediation, and related activities industry (IOcode: 521CI); <6> the other real estate industry (IOcode: ORE); <7> the legal services industry (IOcode: 5411); <8> the water transportation industry (IOcode: 483); <9> the plastics and rubber products industry (IOcode: 326); <10> the rail transportation industry (IOcode: 482); <11> the electrical equipment, appliances, and components industry (IOcode: 335); <12> the textile mills and textile product mills industry (IOcode: 313TT); <13> the truck transportation industry (IOcode: 484); <14> the support activities for mining industry (IOcode: 213); <15> the insurance carriers and related activities industry (IOcode: 524); <16> the other retail industry (IOcode: 4A0); <17> the fabricated metal products industry (IOcode: 332); <18> the securities, commodity contracts, and investments industry (IOcode: 523); <19> the motor vehicle and parts dealers industry (IOcode: 441); <20> the state and local government enterprises industry (IOcode: GSLE); <21> the construction industry (IOcode: 23); <22> the waste management and remediation services industry (IOcode: 562); <23> the warehousing and storage industry (IOcode: 493); <24> the other services, except government industry (IOcode: 81); <25> the petroleum and coal products industry (IOcode: 324); <26> the general merchandise stores industry (IOcode: 452); <27> the miscellaneous manufacturing industry (IOcode: 339); <28> the administrative and support services industry (IOcode: 561); <29> the federal government enterprises industry (IOcode: GFE); <30> the machinery industry (IOcode: 333); <31> the paper products industry (IOcode: 332); <32> the transit and ground passenger transportation industry (IOcode: 485); <33> the performing arts, spectator sports, museums, and related activities industry (IOcode: 711AS); <34> the computer systems design and related services industry (IOcode: 5415); <35> the data processing, internet publishing, and other information services industry (IOcode: 514); <36> the amusements, gambling, and recreation industry (IOcode: 713); <37> the printing and related support activities industry (IOcode: 323); <38> the air transportation industry (IOcode: 481); <39> the oil and gas extraction industry (IOcode: 211); <40> the pipeline transportation industry (IOcode: 486); <41> the food and beverage stores industry (IOcode: 445); <42> the miscellaneous professional, scientific, and technical services industry (IOcode: 5412OP); <43> the wholesale trade industry (IOcode: 42); <44> the primary metals industry (IOcode: 331); <45> the forestry. fishing, and related activities industry (IOcode: 113FF); <46> the publishing industries, except internet includes software industry (IOcode: 511); <47> the accommodation industry (IOcode: 721); <48> the rental and leasing services and lessors of intangible assets industry (IOcode: 532RL); <49> the educational services industry (IOcode: 61); <50> the apparel and leather and allied products industry (IOcode: 315AL); <51> the management of companies and enterprises industry (IOcode: 55); <52> the other transportation equipment industry (IOcode: 3364OT); <53> the farms industry (IOcode: 111CA); <54> the social assistance industry (IOcode: 624); <55> the chemical products industry (IOcode: 325); <56> the computer and electronic products industry (IOcode: 334); <57> the other transportation and support activities industry (IOcode: 487OS); <58> the broadcasting and telecommunications industry (IOcode: 513); <59> the federal general government (nondefense) industry (IOcode: GFGN); <60> the housing services industry (IOcode: HS); <61> the ambulatory health care services industry (IOcode: 621); <62> the motion picture and sound recording industries (IOcode: 512); <63> the hospitals industry (IOcode: 622); <64> the food services and drinking places industry (IOcode: 722); <65> the motor vehicles, bodies and trailers,

and parts industry (IOcode: 3361MV); <66> the state and local general government industry (IOcode: GSLG); <67> the nursing and residential care facilities industry (IOcode: 623); <68> the federal general government (defense) industry (IOcode: GFGD); <69> the utilities industry (IOcode: 22); <70> the food and beverage and tobacco products industry (IOcode: 311FT); <71> the funds, trusts, and other financial vehicles industry (IOcode: 525).

6. Values of Interdependence and Ranks Most Closely Associated with the HS Sector in 2007

The following section is the outcome derived from the model developed in this research associated with 2007's ranks in the housing service sector. This section describes how the housing services sector changed within the economic system between 1997 and 2007, with the rankings most closely related to the housing services sector.

The other real estate sector exhibits a significant change in the value of interdependence with the housing services sector between the year 1997 and the year 2007, at 6th with an interdependence value of 0.041775183 in the year 1997, but at 25th with an interdependence value of 0.002756798 in the year 2007. Also, the sector for 'Federal Reserve banks, credit intermediation, and related activities' shows an interdependence value of 0.12951332 at 5th in the year 1997, but the interdependence value of 0.104464106 at 3rd in the year 2007. This is an unusual case where the value of interdependence of the sector for 'Federal Reserve banks, credit intermediation, and related activities' has fallen, but the ranking has risen. Figure 9 shows 2007' values of interdependence in terms of Housing Service sector.

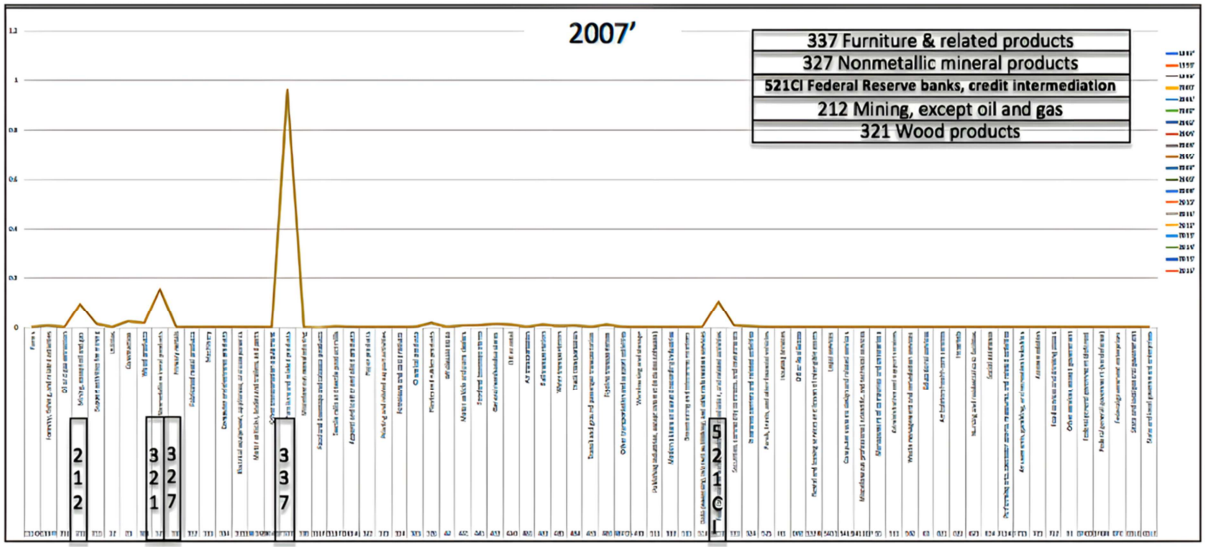


Figure 9. *2007' Values of Interdependence in terms of HS sector.*

The ranks most closely related to the housing service sector in 2007 are included as follows: 1 - the furniture and related products industry (IOcode: 337); 2 - the nonmetallic mineral products industry (IOcode: 327); 3 - the federal reserve banks, credit intermediation, and related activities industry (IOcode: 521CI); 4 - the mining, except oil and gas (IOcode: 212); 5 - the wood products industry (IOcode: 321); 6 - the construction industry (IOcode: 23); 7 - the plastics and rubber products industry (IOcode: 326); 8 - the insurance carriers and related activities industry (IOcode: 524); 9 - the rail transportation industry (IOcode: 482); 10 - the general merchandise stores industry (IOcode: 452); 11 - the support activities for mining industry (IOcode: 213); 12 - the other retail industry (IOcode: 4A0); 13 - the truck transportation industry (IOcode: 484); 14 - the securities, commodity contracts, and investments industry (IOcode: 523); 15 - the motor vehicle and parts dealers industry (IOcode: 441); 16 - the food and beverage stores industry (IOcode: 445); 17 - the pipeline transportation industry (IOcode: 486); 18 - the textile mills and textile product mills industry (IOcode: 313TT); 19 - the water transportation industry (IOcode: 483); 20 - the legal services industry (IOcode: 5411); 21 - the apparel and leather and allied products industry (IOcode: 315AL); 22 - the miscellaneous manufacturing industry (IOcode: 339); 23 - the federal government enterprises industry (IOcode: GFE); 24 - the accommodation industry (IOcode: 721); 25 - the other real estate industry (IOcode: ORE); 26 - the waste management and remediation services industry (IOcode: 562); 27 - the electrical equipment, appliances, and components industry (IOcode: 335); 28 - the fabricated metal products industry (IOcode: 332); 29 - the petroleum and coal products industry (IOcode: 324); 30 - the printing and related support activities industry (IOcode: 323); 31 - the amusements, gambling, and recreation industry (IOcode: 713); 32 - the administrative and support services industry (IOcode: 561); 33 - the machinery industry (IOcode: 333); 34 - the data processing, internet publishing, and other information services industry (IOcode: 514); 35 - the forestry. fishing, and related activities industry (IOcode: 113FF); 36 - the performing arts, spectator sports, museums, and related

activities industry (IOcode: 711AS); 37 - the warehousing and storage industry (IOcode: 493); 38 - the state and local government enterprises industry (IOcode: GSLE); 39 - the educational services industry (IOcode: 61); 40 - the wholesale trade industry (IOcode: 42); 41 - the transit and ground passenger transportation industry (IOcode: 485); 42 - the other transportation equipment industry (IOcode: 3364OT); 43 - the air transportation industry (IOcode: 481); 44 - the miscellaneous professional, scientific, and technical services industry (IOcode: 5412OP); 45 - the paper products industry (IOcode: 332); 46 - the utilities industry (IOcode: 22); 47 - the computer systems design and related services industry (IOcode: 5415); 48 - the housing services industry (IOcode: HS); 49 - the rental and leasing services and lessors of intangible assets industry (IOcode: 532RL); 50 - the publishing industries, except internet includes software industry (IOcode: 511); 51 - the other services, except government industry (IOcode: 81); 52 - the oil and gas extraction industry (IOcode: 211); 53 - the chemical products industry (IOcode: 325); 54 - the broadcasting and telecommunications industry (IOcode: 513); 55 - the motion picture and sound recording industries (IOcode: 512); 56 - the primary metals industry (IOcode: 331); 57 - the computer and electronic products industry (IOcode: 334); 58 - the state and local general government industry (IOcode: GSLG); 59 - the food services and drinking places industry (IOcode: 722); 60 - the federal general government (nondefense) industry (IOcode: GFGN); 61 - the hospitals industry (IOcode: 622); 62 - the social assistance industry (IOcode: 624); 63 - the other transportation and support activities industry (IOcode: 487OS); 64 - the motor vehicles, bodies and trailers, and parts industry (IOcode: 3361MV); 65 - the ambulatory health care services industry (IOcode: 621); 66 - the management of companies and enterprises industry (IOcode: 55); 67 - the funds, trusts, and other financial vehicles industry (IOcode: 525); 68 - the farms industry (IOcode: 111CA); 69 - the federal general government (defense) industry (IOcode: GFGD); 70 - the food and beverage and tobacco products industry (IOcode: 311FT); 71 - the nursing and residential care facilities industry (IOcode: 623).

7. Values of Interdependence and Ranks Most Closely Associated with the HS Sector in 2016

The following section is part of the research's results in the year 2016 that came from a work associated with the interdependency matrix to assess the relationships between various economic sectors within the U.S. economic system. The outcomes of this section are associated with 2016's ranks on the interdependency matrix in terms of the housing service sector. In addition, this section describes how the housing services sector changed within the economic system in the year 2016, related to the rankings most closely associated with the housing services sector.

The ranks most closely related to the housing service sector in the year 2016 show some notable outcomes as follows. The sector for 'Furniture and related products' represents a significant change in the value of interdependence with the housing services sector between the year 1997 and the year 2016, at 1st with an interdependence value of 0.384539028 in the year 1997, but at 1st with an interdependence value of 1.357348146 in the year 2016. This is a unique case where the value of interdependence of the sector for 'Furniture and related products' had fluctuated irregularly and significantly, but the ranking did not change. In 2016, it could be found that the housing services sector and other economic sectors with a value of interdependence of 0.2 or higher were only the top three economic sectors out of seventy-one sectors. Figure 10 shows 2016' values of interdependence in terms of Housing Service sector.

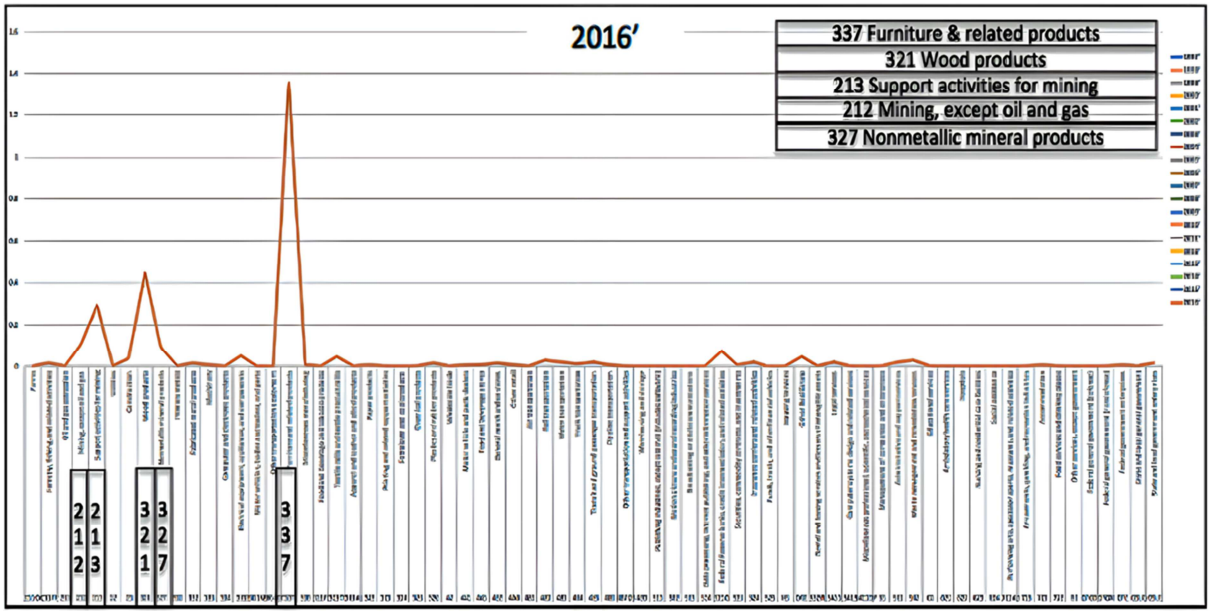


Figure 10. *2016' Values of Interdependence in terms of HS sector.*

The ranks most closely related to the housing service sector in 2016 are included as follows: (1) the furniture and related products industry (IOcode: 337); (2) the wood products industry (IOcode: 321); (3) the support activities for mining industry (IOcode: 213); (4) the mining, except oil and gas (IOcode: 212); (5) the nonmetallic mineral products industry (IOcode: 327); (6) the federal reserve banks, credit intermediation, and related activities industry (IOcode: 521CI); (7) the electrical equipment, appliances, and components industry (IOcode: 335); (8) the textile mills and textile product mills industry (IOcode: 313TT); (9) the other real estate industry (IOcode: ORE); (10) the construction industry (IOcode: 23); (11) the rail transportation industry (IOcode: 482); (12) the waste management and remediation services industry (IOcode: 562); (13) the transit and ground passenger transportation industry (IOcode: 485); (14) the legal services industry (IOcode: 5411); (15) the water transportation industry (IOcode: 483); (16) the administrative and support services industry (IOcode: 561); (17) the insurance carriers and related activities industry (IOcode: 524); (18) the forestry. fishing, and related activities industry (IOcode: 113FF); (19) the general merchandise stores industry (IOcode: 452); (20) the fabricated metal products industry (IOcode: 332); (21) the plastics and rubber products industry (IOcode: 326); (22) the state and local government enterprises industry (IOcode: GSLE); (23) the truck transportation industry (IOcode: 484); (24) the other retail industry (IOcode: 4A0); (25) the food and beverage stores industry (IOcode: 445); (26) the federal government enterprises industry (IOcode: GFE); (27) the paper products industry (IOcode: 332); (28) the machinery industry (IOcode: 333); (29) the pipeline transportation industry (IOcode: 486); (30) the miscellaneous manufacturing industry (IOcode: 339); (31) the securities, commodity contracts, and investments industry (IOcode: 523); (32) the accommodation industry (IOcode: 721); (33) the motor vehicle and parts dealers industry (IOcode: 441); (34) the printing and related support activities industry (IOcode: 323); (35) the air transportation industry (IOcode: 481); (36) the computer systems design and related services industry (IOcode: 5415); (37) the petroleum and coal products industry (IOcode: 324); (38) the amusements, gambling, and recreation industry (IOcode: 713); (39) the performing arts, spectator sports, museums, and related activities industry (IOcode: 711AS); (40) the oil and gas extraction industry (IOcode: 211); (41) the primary metals industry (IOcode: 331); (42) the rental and leasing services and lessors of intangible assets industry (IOcode: 532RL); (43) the warehousing and storage industry (IOcode: 493); (44) the computer and electronic products industry (IOcode: 334); (45) the data processing, internet publishing, and other information services industry (IOcode: 514); (46) the other transportation equipment industry (IOcode: 3364OT); (47) the wholesale trade industry (IOcode: 42); (48) the apparel and leather and allied products industry (IOcode: 315AL); (49) the educational services industry (IOcode: 61); (50) the chemical products industry (IOcode: 325); (51) the motion picture and sound recording industries (IOcode: 512); (52) the publishing industries, except internet includes software industry (IOcode: 511); (53) the utilities industry (IOcode: 22); (54) the other services, except government industry (IOcode: 81); (55) the management of companies and enterprises industry (IOcode: 55); (56) the miscellaneous professional, scientific, and technical services industry (IOcode: 5412OP); (57) the other transportation and support activities industry (IOcode: 487OS); (58) the broadcasting and telecommunications industry (IOcode: 513); (59) the social assistance industry (IOcode: 624); (60) the farms industry (IOcode: 111CA); (61) the food services and drinking places industry (IOcode: 722); (62) the state and local general government industry (IOcode: GSLG); (63) the housing services industry (IOcode: HS); (64) the federal general government (nondefense) industry (IOcode: GFGN); (65) the motor vehicles, bodies and trailers, and parts industry (IOcode: 3361MV); (66) the nursing and residential care facilities industry (IOcode: 623); (67) the hospitals industry (IOcode: 622); (68) the ambulatory health care services industry (IOcode: 621); (69) the food and beverage and tobacco products industry (IOcode: 311FT); (70) the federal general government (defense) industry (IOcode: GFGD); (71) the funds, trusts, and other financial vehicles industry (IOcode: 525).

8. Value of Interdependence in Terms of the Housing Service Sector

Table 1 represents the value of interdependency matrix based on rankings in terms of the housing service sector. The outcome of the research represents the values of interdependency between seventy-one sectors in terms of the housing service sector, and the interdependency matrix's ranking lists all economic sectors from those most affected to the least affected in relation to the HS sector. The numbers indicate interdependency values between economic sectors and the rankings from the highest value to the lowest value with respect to the HS sector.

Here are several notable results you should pay attention to. First, the construction (23) sector showed a significant change in the value of its interdependence with the Housing Services sector between 1997 and 2016. It ranked 21st with an interdependence value of 0.007486742 in 1997, 6th in 2007 with an interdependence value of 0.0300083268, and 10th in 2016 with an interdependence value of 0.039743486. Second, the mining, except oil and gas (212) sector showed that the value of interdependence with the housing services sector changed between 1997 and 2016, but the ranking did not change. It ranked 4th with an interdependence value of 0.162507571 in 1997, 4th in 2007 with an interdependence value of 0.098601259, and 4th in 2016 with an interdependence value of 0.105939069. Third, the plastics and rubber products sector (326) represented that there were some fluctuations in the value of its interdependence with the

Housing Services sector between 1997 and 2016. It ranked 9th with an interdependence value of 0.028609656 in 1997, 7th in 2007 with an interdependence value of 0.016210459, and 21st in 2016 with an interdependence value of 0.014499302. Fourth, the electrical equipment, appliances, and components (335) sector showed a decreasing trend and then rose again in value and ranking of interdependence with the housing services sector between 1997 and 2016. It ranked 11th with an interdependence value of 0.022694635 in 1997, 27th in 2007 with an interdependence value of 0.00265722, and 7th in 2016 with an interdependence value of 0.049039423. Fifth, the support activities for mining (213) sector consistently showed an increasing trend in the value and ranking of interdependence with the housing services sector between 1997 and 2016. It ranked 14th with an interdependence value of 0.013785485 in 1997, 11th in 2007 with an interdependence value of 0.012299585, and 3rd in 2016 with an interdependence value of 0.291577813.

Table 1. *Value of Interdependency Matrix Based on Rankings in Terms of The Housing Service Sector.*

(HS)	1997		2007		2016	
	Rank	Value	Rank	Value	Rank	Value
23	21st	0.007486742	6th	0.0300083268	10th	0.039743486
212	4th	0.162507571	4th	0.098601259	4th	0.105939069
326	9th	0.028609656	7th	0.016210459	21st	0.014499302
5411	7th	0.038767784	20th	0.003798	14th	0.019871919
335	11th	0.022694635	27th	0.00265722	7th	0.049039423
313TT	12th	0.019883679	18th	0.005738342	8th	0.047938017
213	14th	0.013785485	11th	0.012299585	3rd	0.291577813
524	15th	0.012778563	8th	0.013651037	17th	0.018265184

Figure 11 shows the top five economic sectors of values of Interdependence in terms of the Housing Service Sector (HS) for 20 years. The highest relationship with the HS sector in the interdependency matrix was Furniture and related products sector (IO code 337) out of the seventy-one sectors for 20 years. The second most related sector to the HS sector was Wood products sector (IO code 321) out of the seventy-one sectors. The third most related sector to the HS sector was Nonmetallic mineral products sector (IO code 327) out of the seventy-one sectors. The fourth most related sector to the HS sector was Mining, except oil and gas sector (IO code 212) out of the seventy-one sectors. The fifth most related sector to the HS sector was Federal Reserve banks, credit intermediation (IO code 521CI) out of the seventy-one sectors.

The trends based on the global financial crisis (GFC) of 2008 provided interesting points in the findings of this research. As of 2008, the interdependence values of construction (23) and wood products (321) in terms of the HS sector showed a tendency to increase, while the interdependence values of the furniture and related products (337) and federal reserve banks, credit intermediation, and related activities (521CI) showed a sharp decline.

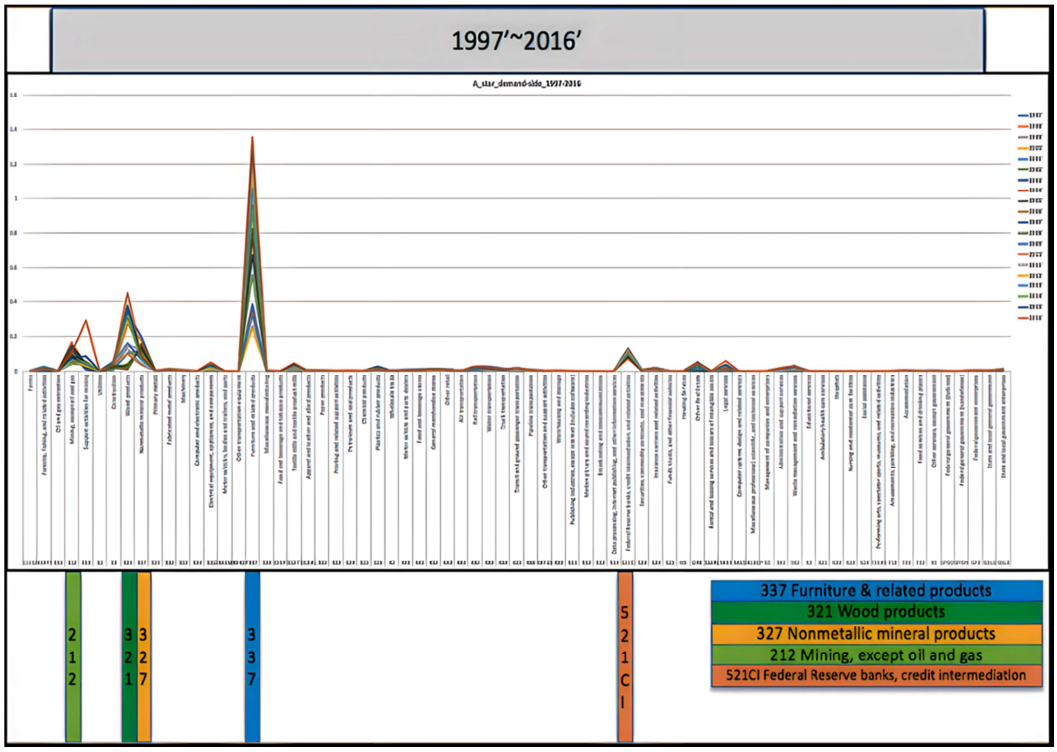


Figure 11. *Top Five Sectors of Values of Interdependence in Terms of Housing Service Sector.*

9. Annual Variation of Interdependency Matrix in Terms of the Housing Service Sector

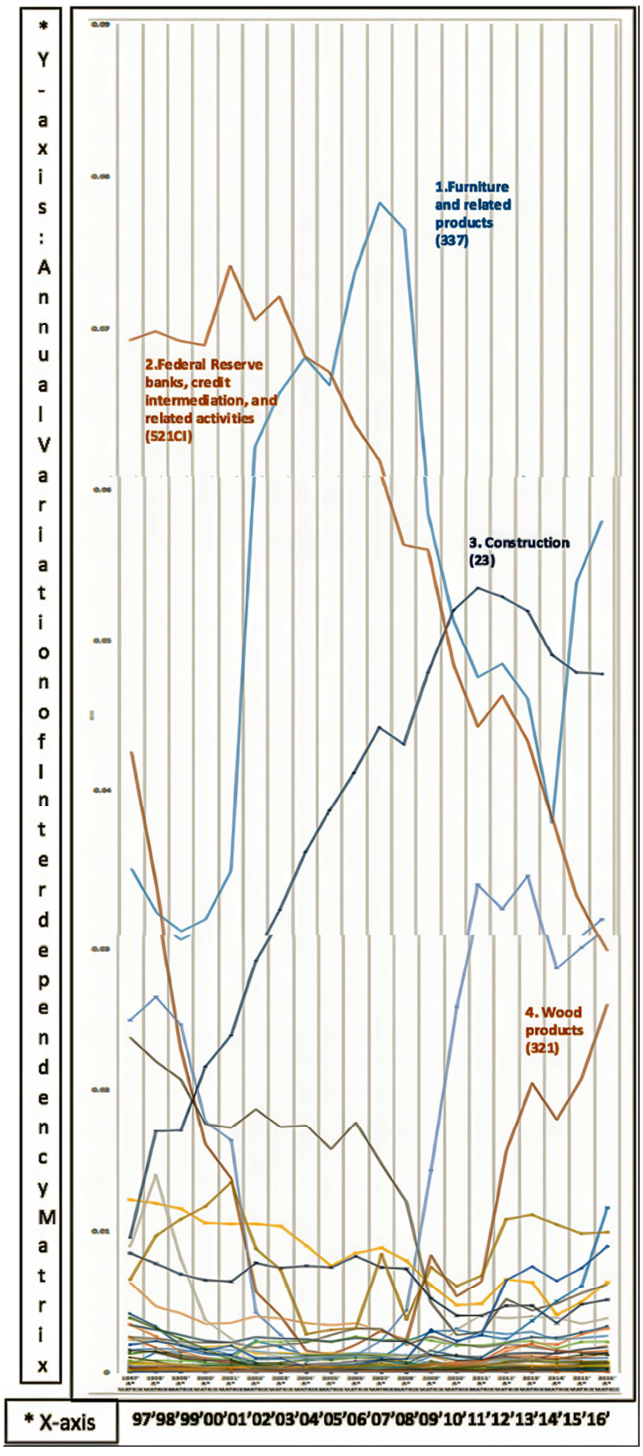


Figure 12. *Annual Variation of Interdependency Matrix in Terms of Housing Service Sector.*

Annual variation of the interdependency matrix in terms of the HS sector represents how the value of the interdependence between the housing-reliant sectors and all other economic sectors had been changed and fluctuated over the past two decades. Figure 12 shows the annual variation of the interdependency matrix on the demand side between the HS sector and all other economic sectors for the past twenty years. The X-axis represents the years for the past two decades, and the Y-axis represents the values of interdependence with the HS sector. IO code 337 (Furniture and related products sector) was the most interdependent one to the HS sector in the technical coefficient of interdependency matrix from 1997 to 2016. The graph about the annual variation of the technical coefficient of the interdependency matrix indicates the annual value of interdependence for IO code 337 (Furniture and related products sector) was an upward curve from 2000 to 2007, and this curve hit its lowest point between 1999 and 2000. Since then, the annual value for the furniture and related products sector rose (IO code 337), showed a declining trend from 2007 to 2014, and then rose again from 2014 to 2016. IO code 521CI (Federal reserve banks, credit intermediation, and related activities sector) was one of the most affected sectors to the HS sector in the interdependency matrix in terms of the HS sector spanning from 1997 to 2016. The graph about the annual variation of the interdependency matrix showed that the annual value of interdependence of IO code 521CI (Federal reserve banks, credit intermediation, and related activities sector) was an upward curve from 1997 to 2001 and reached its lowest point in 2016. Since 2001, the annual value of the federal reserve banks, credit intermediation, and related activities sector had steadily decreased from 2001 to 2016. IO code 23 (Construction sector) was one of the most affected sectors based on the HS sector in the interdependency matrix in terms of the housing service sector for the past twenty years. The graph about the annual variation of the interdependency matrix represented that the annual value of interdependence of IO code 23 (Construction sector) was an upward curve from 1997 to 2011 and reached its highest point in 2011. Since then, the annual value of the construction sector (IO code 23) has shown a declining trend from 2011 to 2016. The construction sector, the federal reserve banks, credit intermediation, and related activities sector, the wood sector, and the furniture and related products sector had interdependence values of greater than 0.02. However, based on the demand side of the HS sector in the interdependency matrix, the majority of the rest of the economic sectors for twenty years had interdependence values of less than 0.02.

10. Conclusion

There is a possibility that people only associate building construction or real estate with their housing service sector. However, virtually all end-user products rely on the housing service to varying degrees. The HS sector is the vital and essential infrastructure of the communities that provides critical services. This service sector serves as the cornerstone of individuals and households, security, various businesses, economic activity, and operations and maintenance of local and regional governments. Hence, the resilience and security

of the housing service infrastructure must be ensured.

Moreover, improving the housing service sector's security can be of utmost significance with regard to the recovery from or resistance to adversely exogenous factors. Cumulative damages and increased risks to the housing service infrastructure owing to increased instances of negatively exogenous factors can ultimately lead to increased potential risks in terms of physical, societal, and economic impacts. On the flip side, the economic impact assessment caused by additional capital investments in the HS sector can lead to help in managing appropriate and efficient investment strategies in the housing service sector.

In fact, inappropriate and inefficient assessment of the HS sector in terms of the economic impact may have fatal consequences for over 300 million people in the United States. On the other hand, an appropriate and efficient assessment of the HS sector in terms of the economic impact may lead to a positive impact not only on economic sectors closely related to the HS sector but also on the entire U.S. economic system. Therefore, this research defined the value of interdependence in terms of the housing service sector and analyzed deterministic relationships among various sectors within a U.S. economic system. It will help to measure the economic impacts of the housing service infrastructure. This approach of predicting the economic impacts from the loss of the housing service sector or additional capital investment in the housing service sector can help in creating a paradigm shift in the current state of practice.

One of the outcomes of this research is that when the loss of the housing service sector from adversely exogenous factors, it is possible to minimize damages by prioritizing strategic recovery actions based on the type of loss. It aims to strengthen the resilience of the housing services infrastructure by reducing associated risks and damages in the future, and to establish the prioritization of the housing service infrastructure's resilience. Another outcome of this research is that when there is additional capital investment in the housing service sector, it can lead to the prioritization of investment actions. This can be aimed at maximizing related benefits in the future, thereby building the prioritization for the housing service infrastructure's profits. The application of the interdependency matrix can more accurately predict economic impacts in terms of the HS sector resulting from loss and damages that are caused by adversely exogenous factors and help to prioritize investment actions for maximizing related profits of the HS sector in the future.

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