

Interdependence Across the National Critical Functions

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Abstract

In 2019, the Cybersecurity and Infrastructure Security Agency (CISA) introduced a set of 55 National Critical Functions (NCFs) to “guide national risk management efforts”. The NCFs were a fundamental shift aimed at enabling the identification and prioritization of systemic risks to critical infrastructure. Additionally, they highlight the importance of interdependence. The interdependence of NCFs, driven by a variety of processes including the output linkages of one to another, can result in the creation of systemic risk out of seemingly isolated risks. The fundamental drivers are familiar to the risk analysis community. Cascading risk can drive the potential propagation of failures across NCFs while common cause failures can result in simultaneous failure of multiple NCFs due the same underlying driver. These systemic risks can traverse network dependencies ranging from economic to software to policy. Additionally, NCF interdependencies can also have positive consequences through enhanced resilience; following a disruption to a pipeline, for example, alternative transportation modes, such as rail, might be used to overcome the consequences of the disruptions. In this paper, we provide a novel interpretation of NCFs to enhance their use for research by the risk analysis community. We provide a conceptual framework of NCF interdependence leveraging a review of relevant literatures. We then provide a path to mapping of many (though not all) NCFs to economic sectors enabling their study using accepted methods like input-output analysis. We use this mapping to provide value-added multipliers for each NCF and a ranking to indicate their relative interdependence within economic networks. In examining economic interdependence, we found that Operate Core Network, Provide Capital Markets and Investment Activities, Provide Radio Broadcast Access Network Services, and Educate and Train rise to the top of the list when NCFs are ranked by their economic multipliers. Finally, we discuss our investigations on the role of interdependence across NCFs and provide recommendations on how policymakers should think about them and how analysts can model them.

Acknowledgements

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1 Introduction

In April 2019, the Cybersecurity and Infrastructure Security Agency (CISA) on behalf of the National Risk Management Center (NRMC), both part of the U.S. Department of Homeland Security (DHS), introduced a significant update to the National Infrastructure Protection Plan by introducing a set of National Critical Functions (NCFs) (CISA 2019).

Aimed at addressing risks that cut across sectors and enabling their identification, NCFs are

“[t]he functions of government and the private sector so vital to the United States that their disruption, corruption, or dysfunction would have a debilitating effect on security, national economic security, national public health, or safety, or any combination thereof” (CISA 2022)

Table 1 lists the set of 55 NCFs grouped into four the categories of: connect, distribute, manage, and supply while Appendix A provides definitions for each NCF.

Table 1. The National Critical Functions

Connect	Distribute	Manage	Supply
<ul style="list-style-type: none"> Operate Core Network Provide Cable Access Network Services Provide Internet Based Content, Information, and Communication Services Provide Internet Routing, Access, and Connection Services Provide Positioning, Navigation, and Timing Services Provide Radio Broadcast Access Network Services Provide Satellite Access Network Services Provide Wireless Access Network Services Provide Wireline Access Services 	<ul style="list-style-type: none"> Distribute Electricity Maintain Supply Chains Transmit Electricity Transport Cargo and Passengers by Air Transport Cargo and Passengers by Rail Transport Cargo and Passengers by Road Transport Cargo and Passengers by Vessel Transport Materials by Pipeline Transport Passengers by Mass Transit 	<ul style="list-style-type: none"> Conduct Elections Develop and Maintain Public Works and Services Educate and Train Enforce Law Maintain Access to Medical Records Manage Hazardous Materials Manage Wastewater Operate Government Perform Cyber Incident Management Capabilities Prepare for and Manage Emergencies Preserve Constitutional Rights Protect Sensitive Information Provide and Maintain Infrastructure Provide Capital Markets and Investment Activities Provide Consumer and Commercial Banking Services Provide Funding and Liquidity Services 	<ul style="list-style-type: none"> Exploration and Extraction of Fuels Fuel Refining and Processing Fuels Generate Electricity Manufacture Equipment Produce and Provide Agricultural Products and Services Produce and Provide Human and Animal Food Products and Services Produce Chemicals Provide Metals and Materials Provide Housing Provide Information Technology Products and Services Provide Materiel and Operational Support to Defense Research and Development Supply Water

Connect	Distribute	Manage	Supply
		<ul style="list-style-type: none"> • Provide Identity Management and Associated Trust Support Services • Provide Insurance Services • Provide Medical Care • Provide Payment, Clearing, and Settlement Services • Provide Public Safety • Provide Wholesale Funding • Store Fuel and Maintain Reserves • Support Community Health 	

The set of 55 NCFs is comprehensive in its representation of functions ranging from highly specific sectors (e.g., ‘Provide Positioning, Navigation, and Timing Services’) to broad concepts (e.g., ‘Preserve Constitutional Rights’). However, the NCFs do not exist in isolation of one another. Any analysis of their risks should account for how the NCFs relate to one another, how these connections could give rise to cascading impacts, and whether and how NCF interdependence might change our view of risk (by, for example, amplifying existing risks or by creating new systemic risks across NCFs).

In this perspective, we expand on Lauland, Preston et al. (2022)’s risk assessment of NCFs during the COVID-19 pandemic to investigate the role of interdependence within the NCFs, how policymakers should think about them, and how analysts can model them. Specifically, we address the following questions:

- What are the ways in which NCFs might be interdependent?
- What are the implications of NCF interdependence for assessing risk to NCFs?
- Which NCFs are interdependent with one another?
- How can NCF interdependence be quantified?

We use lessons from studies on risk analysis and economic literature to describe how policy makers can think about NCF interdependence. Second, we present a conceptual model of interdependence within the NCFs by describing, for each NCF, how that NCF depends on the outputs of other NCFs and which NCFs use its outputs. Third, we focus on economics as the connective tissue between the NCFs and present an approach under which widely used methods in economics—input-output (IO) analysis—can be used to model and measure NCF interdependencies. We intend for the two types of analysis—conceptual and economic—to be used in tandem. In some cases, the economic analysis provides a strong decision aid to identify NCFs with significant levels of interdependence; in others, the conceptual analysis provides a

useful decision aid where data are sparse. Finally, we conclude with lessons learned and steps for future research.

2 Interdependence Typologies

2.1 Interdependence Frameworks

In this section we draw on literature to understand interdependence between NCFs. A natural place to start is the DHS lexicon¹ which defines interdependence as a “mutually reliant relationship between entities (objects, persons, or groups)”. Describing these relationships as a system can further aid in developing an analytical framework to understand interdependence.

Jonsson (2000) describes types of interconnectivity within *infrasystems* (a shortened term that describes systems of infrastructure). An infrasystem can be described with a series of nodes, links, and flows across each link. These flows can be distributive (directed away from a central node to other nodes), accumulative (directed toward a central node from other nodes), or communicative (in which flows are in both directions).

Several systems have distinguished between types of interdependencies. In Rinaldi, Peerenboom et al. (2001), the authors define *infrastructure interdependencies* as the “connections among agents in different infrastructures in a general system of systems” along four dimensions of interdependence: physical, cyber, geographical, and logical. Zimmerman (2001) defines two types of interdependence: *spatial* and *functional*. With some similarity to Rinaldi, Peerenboom et al. (2001), Dudenhoefter, Permann et al. (2006) outline four categories of interdependence: physical, geospatial, policy, and informational. Additionally Zhang and Peeta (2011) categorize four types of interdependence: functional, physical, budgetary, and market and economic. We summarize each of these categories below in Table 2.

Table 2. Interdependence Frameworks

Source	Type	Definition
Rinaldi, Peerenboom et al. (2001)	Physical	An output of one infrastructure or system is dependent on the output of another.
	Cyber	A system's state is dependent on the output of information infrastructure.
	Geographical	A system's state can be affected by another system due to its physical proximity.
	Logical	A system is dependent on the state of another system due to some connection not captured in physical, cyber, or geographic interdependence.
Zimmerman (2001)	Spatial	Similar to Rinaldi, Peerenboom et al. (2001)'s definition of geographical interdependence.

¹ Management Directorate, D. (2017). DHS Lexicon Terms and Definitions. [Instruction Manual 262-12-001-01](#). U. S. D. o. H. Security.

	Functional	Systems rely on each other to operate.
Dudenhoeffer, Permann et al. (2006)	Physical	Similar to Rinaldi, Peerenboom et al. (2001)'s definition of physical interdependence.
	Geospatial	Similar to Rinaldi, Peerenboom et al. (2001)'s definition of geographical interdependence.
	Informational	Similar to Rinaldi, Peerenboom et al. (2001)'s definition of cyber interdependence with the addition of other forms of information flows.
	Policy	Infrastructure systems that are dependent due to policy decisions.
Zhang and Peeta (2011)	Functional	Similar to Rinaldi, Peerenboom et al. (2001)'s and Dudenhoeffer, Permann et al. (2006)'s definition of functional and physical interdependence.
	Physical	Similar to Rinaldi, Peerenboom et al. (2001)'s and Dudenhoeffer, Permann et al. (2006)'s definition of geospatial interdependence.
	Budgetary	The financial relationship between the government and infrastructures through public financing.
	Market And Economic	The relationship between infrastructures that share economic systems and customers, as well as the relationship between the government and infrastructures through regulation, legislation, and policy.

Additionally, Wallace, Mendonca et al. (2003) categorize interdependent infrastructures as dependent, mutually dependent, or colocated. To be dependent, an infrastructure must meet one of the following conditions:

- “[T]he infrastructure requires as input one or more services from another infrastructure in order to provide some other service” (p. 5).
- “[S]ome physical components and/or activities of the infrastructure used in providing the service are shared with one or more other infrastructures” (p. 5).
- “[E]ither the infrastructure or some other infrastructure (but not both) can be in use during provision of the service” (p. 5).

2.2 Interdependence and Risk of Failure

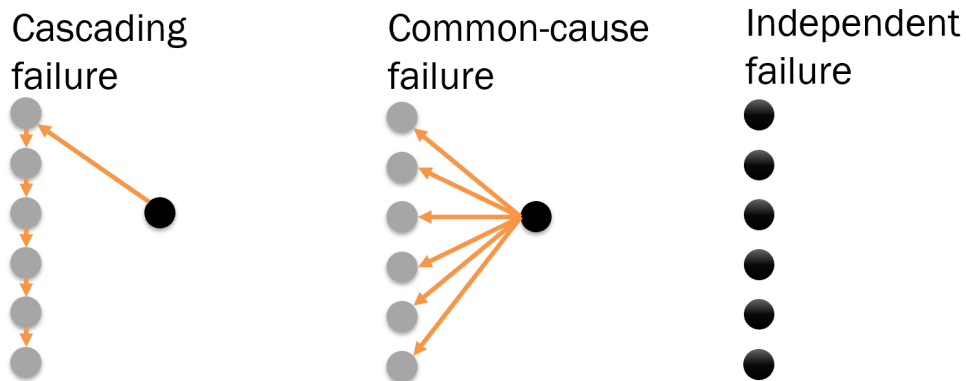
Despite the range of categories of interdependence, the risks that it creates can be more succinctly described as *cascading*, *common-cause*, and *independent* risks as shown below and depicted in Figure 1,

- *Cascading failure*: the potential propagation of failures along a system, or a so-called “domino” effect. Power lines, for example, are a common example in which the potential for cascading failures is a significant source of risk.
- *Common-cause failure*: the risk of several subsystems failing because of the same driver. In practice, floodplains offer a frequent source of common-cause failure in which multiple houses flood simultaneously because of their shared location.

- *Independent failure*: the event of multiple simultaneous failures across a system due to entirely separate events. For example, a car on the north side of a city crashes into a transformer, causing a blackout on that side of the city, while a car on the south side of the city crashes into a transformer, causing a simultaneous blackout in the south side. Although the entire city has a blackout, it was caused by two unrelated events that occurred at the same time.

Of course, these events need not be physical. For example, Welburn and Strong (2022), describe the role of cascading and common-cause failures in cyberspace related to digital connections.

Figure 1. Cascading, Common-Cause, and Independent Failures



In addition to being disrupted by a cascading or common cause external to the NCFs, such as a hurricane, a key challenge of interdependence is the disruption or failure of an NCF can lead to cascading or common-cause failure of other NCFs through one or more of the interdependence types described in Table 2.

2.3 A Conceptual Understanding of NCF Interdependence

As suggested by the academic literature, interdependence among NCFs can come from a variety of different processes. For example, the outputs of one NCF can be inputs to another NCF, creating interdependence (e.g., numerous NCFs have a functional dependence on the ‘Distribute Electricity’). We build on the analyses of infrastructure interdependencies in the literature to provide a concise framework to apply to the NCFs. The categories of interdependence described in this framework are not mutually exclusive. The proposed framework describes unique linkages between the NCFs that should be analyzed in more detail, as well as the potential risk characteristics associated with these interdependencies. Building on the literature discussed above, we identified three categories of NCF interdependence: functional, co-located, and policy, as defined in Table 3.

Table 3. NCF Interdependence Types

Type	Definition	Example
Functional	The result of a system being dependent on the inputs and outputs of another other system to operate. These interdependencies can be partially described economically.	The NCF ‘Produce and Provide Agricultural Products and Services’ relies on inputs from other NCFs, such as ‘Manage Wastewater’ or ‘Transport Cargo and Passengers by Road’.
Colocated	The result of proximity between two or more systems’ functions. These infrastructures might not typically be interdependent, but, because of their proximity, failure in one could lead to failure in the other. Colocated links are shared between infrastructure systems with limited space.	Jonsson (2000) describes internet service cables placed in a preexisting sewer tunnel rather than digging a separate tunnel. A disruption to the sewer tunnel could cause a disruption to the internet service cables due to their colocation. Applied to NCFs, this type of interdependence could describe the relationship between the ‘Manage Wastewater’ and the ‘Provide Internet Routing, Access, and Connection Services’ NCFs.
Policy	The relationship between a system and the rules, regulations, information, and budgets determined by government.	The ‘Conduct Elections’ NCF is interdependent with the ‘Operate Government’ NCF as local and state governments are responsible for setting rules and processes related to conducting elections. Similarly, the ‘Manage Wastewater’ NCF is often interdependent with ‘Operate Government’ because federal, state, and local governments might all regulate different aspects of wastewater-management systems.

In some cases, describing the nodes and linkages that make up infrastructure systems as a network can provide a clearer understanding of how the different systems are organized. In the next section, we provide a more detailed analysis focused on the economic system and the role of functional interdependence. While we specifically selected this form of interdependence due to readily available data on functional dependencies in economic linkages, this perspective can inform future analysis into other forms of NCF interdependence.

3 Estimating NCF Economic Interdependencies

One approach for considering interdependencies of the NCFs is to focus on the production and allocation functions of sectors associated with the NCFs provision. Our approach maps each of the NCFs to one or more economic sectors. We then exploit the input-output tables as both production and allocation functions to estimate the magnitude of interconnections as well as the aggregate economic impact potential of the disruption to an NCF. Our approach builds from the seminal work of Leontief (1966) to consider input-output linkages that have widely been used to estimate regional impacts of policy change.

Input-output (IO) analysis uses a structural representation of the economy based on a double entry accounting system where columns represent production and consumption functions and rows represent allocations within the system. Within the risk analysis community, IO models have provided a capable tool for estimating how surprise events, driven by realized hazards and threats, flow through an economy. For example, Hallegatte (2008), Avelino and Dall'Erba (2019), and Li et al. (2013) study the economic impacts of natural disasters; Santos and Haines (2004), Cheng et al. (2006), and Gordon et al. (2007) have employed IO methods to study the impacts of terrorism; and Santos, Haines et al. (2007), Dreyer, Jones et al. (2018), and Welburn and Strong (2022) have employed IO models to study cyberattacks and the role of interdependence, economic impacts, and systemic risk.

To better understand the economic impact of a disruption to any of the NCFs, we considered two aspects of the functions: (1) what are the economic sectors that are directly affected by the NCFs? If disrupted, how would those flow through the supply chain to affect other sectors? and (2) are there redundancies across the NCFs where if one function is compromised a substitute function could be used in its place?

3.1 Analysis of NCF Interdependence Using IMPLAN

The national IO tables available from BEA or IMPLAN provide a starting point for considering the economic impacts of disruptions. The most reliable IO tables are at three-digit NAICS level or a rough equivalent. In many cases the NCFs directly match a specific sector, in some cases, a single NCF is mapped to multiple sectors, in other cases multiple NCFs map to a single sector, and finally for some NCFs we do not have a clear mapping to any economic sectors. Our approach uses the IMPLAN sectoring but could easily be modified to NAICS to use the BEA data. These four categories are:

1. 1-1 mapping from NCF to IMPLAN (e.g., 'Transport Cargo and Passengers by Air' NCF maps directly to 'Air Transportation'). These NCFs provide an opportunity to do IO analysis directly.

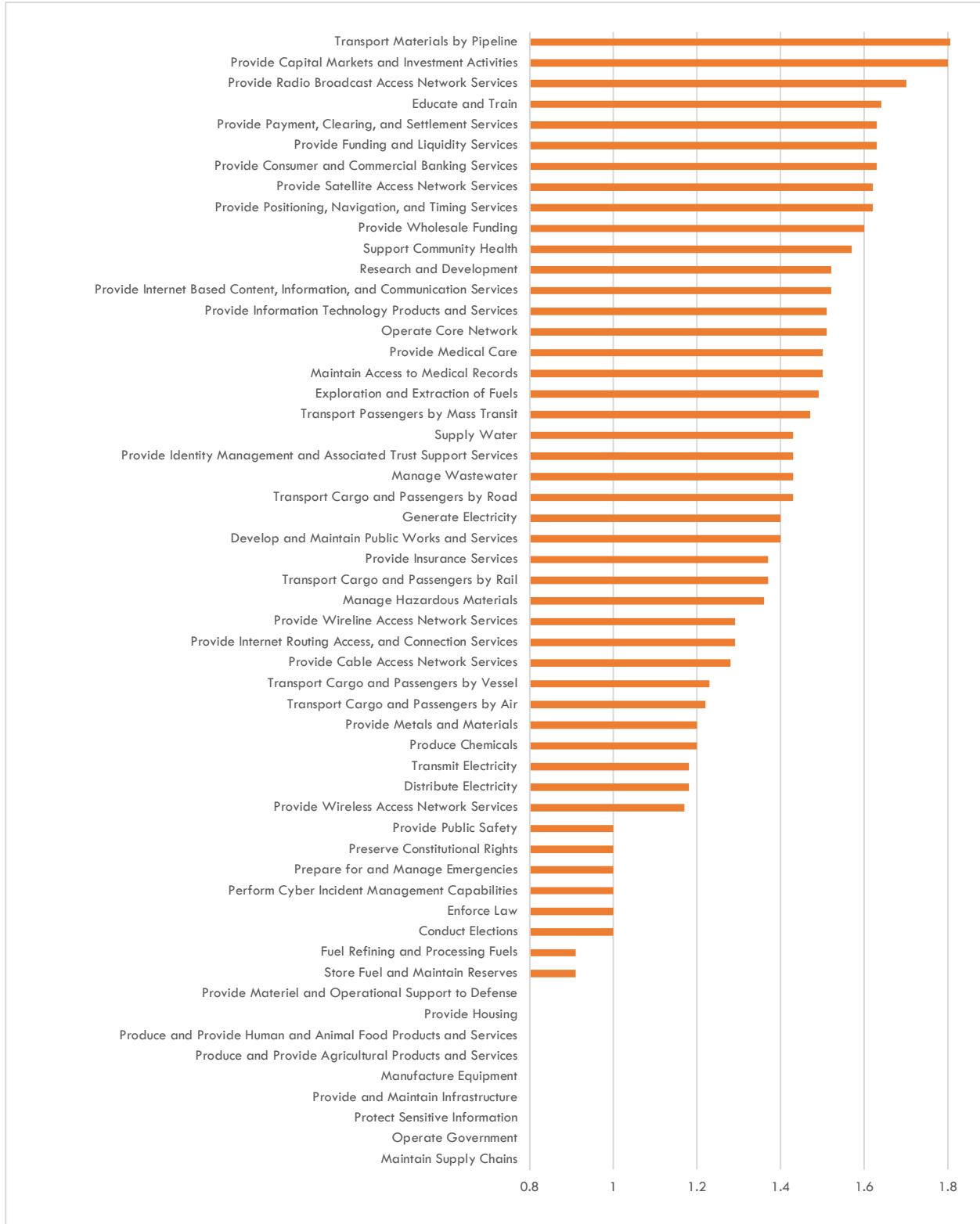
2. 1-N mapping from NCF to IMPLAN (e.g., “Operate Core Network” NCF is a collection of communications networks “Provide Cable Access Network Services” and “Provide Wireless Access Network Services”) which, importantly, indicate sectors that could act as substitutes following a disruption.
3. N-1 mapping from NCF to IMPLAN (e.g., ‘Distribute Electricity’ and ‘Transmit Electricity’ to ‘Distribute and Transmit Electricity’). This requires us to aggregate some of the IMPLAN sectors to be able to do analysis.
4. Some other NCFs have no clear analog to an economic sector (e.g., ‘Maintain Supply Chains’ and ‘Operate Government’). As such, we can either use the assumption that these are federal and state and local government operations or remove them from the analysis.

Mapping NCFs to sectors allows economy wide models to assess the indirect and direct impacts of disruptions to NCFs. Notably, while we discuss national level impacts, it is additionally possible to downscale impacts of NCF disruptions to a more regional level, which is particularly helpful for more regionally based NCFs (e.g., ‘Distribute Electricity’). Thus, the economywide economic impacts can be estimated using a traditional IO approach. But because most of these NCFs are in more-basic industries, the Leontief IO model would capture little of the economic impact and a Ghoshian IO approach would need to be used.² Our concern is that the downstream impacts from disruptions of NCFs is likely to be much larger than the upstream. The traditional Leontief approach only considers upstream impacts as such we incorporate the downstream impacts using an approach developed in Welburn and Strong (2022) and similar to that of Santos and Haimen (2004) and Santos, Haimen et al. (2007).

In Appendix B we show the full results, including the NCF-to-sector crosswalk. Here, we briefly summarize these results and our interpretation. In Figure 2, we depict estimated multiplier effects which can be interpreted as the aggregate impact of production from each NCF. This is based on the Ghoshian approach to the IO analysis and considers the downstream impacts. For example, at the top of the list, the multiplier states that, every \$1 produced by the ‘Transport Materials by Pipeline’ NCF generates \$1.8 to the system of NCFs. This aggregate impact is born out of functional interdependence as the outputs (products and services) of each NCF are used as inputs to production by other NCFs. That means that the ‘Operate Core Network’ NCF, for example, is high on the ranking of NCFs by multiplier effect because it can provide the backbone of numerous businesses and services across NCFs.

² For one comparison of the Leontief and Ghoshian models, see Oosterhaven, J. (1996). "Leontief versus Ghoshian Price and Quantity Models." *Southern Economic Journal* **62**(3): 750.

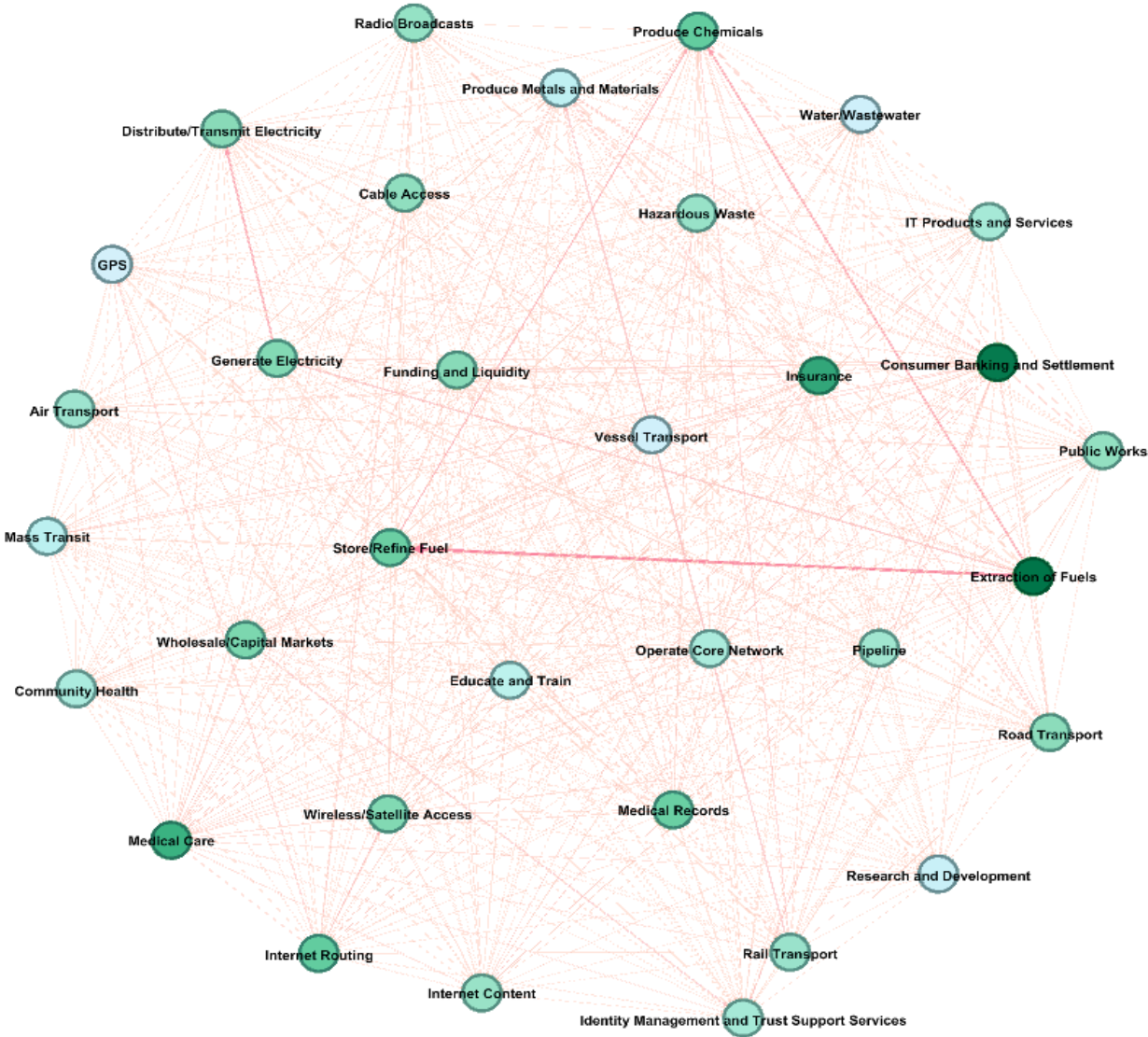
Figure 2. The Estimated NCF Interdependence Multiplier Effect



Furthermore, in interpreting the results in Figure 2, each multiplier is inherently unitless. Each indicates relative criticality for a specific point (either steady state or in a crisis), but each NCF can further differ in size. One NCF with a lower multiplier but very large total output might have more impact than an NCF with a higher multiplier but small output. That is, total economic impact is a product of the value-added multiplier and the total value added.

While Figure 2 presents the numeric results of IO analysis in terms of multipliers, Figure 3 displays the resulting system of NCFs as a network. Within this network, lines (e.g., arcs or links) demonstrate connections between NCFs, while the darker the shades of each line reflect the value of each linkage between NCFs measured in the dollars flowing between each. (The full details of the connections depicted in Figure 3 are shown in the matrix for Appendix B.) In Figure 3, each node represents an NCF, and the links represent the IO linkages. Each node is color coded. The darker the color of a node, the greater its overall *economic* impact, and the darker the color of each edge, the stronger the IO linkage is between them.

Figure 3. Network of NCF interdependence



Additionally, within the network in Figure 3, nodes toward the center carry higher centrality—a higher level of influence on other NCFs through higher interdependence—than nodes toward the periphery. For example, the ‘Provide Funding and Liquidity Services’ NCF sits near the center of the top half of the graph because it supports significant economic activity across the NCFs. Similarly, the ‘Extract Fuels’ and ‘Store Fuel and Maintain Reserves’ NCFs also carry high centrality. In terms of interdependence, the higher the level of an NCFs centrality within the graph of Figure 3, the higher the level of its functional economic interdependence.

Of course, the ties shown in Figure 3 are all in dollar terms, which might omit other types of functional interdependence (e.g., software), in addition to colocated and policy interdependencies. Additionally, by definition, every NCF is *critical*; for example, we expect that everyone reading this perspective appreciates the critical importance of the ‘Research and Development’ NCF.

4 Lessons Learned

While each National Critical Function (NCF) is critical, none lives in isolation. Each provides a function on which other NCFs rely. NCF risk analysis should fully consider the implications of this interdependence. Of course, interdependence is complex—it cuts across numerous dimensions, from the social, to the political, to the digital. We focused on one important dimension through an analysis of economic interdependence. Analysis such as that produced in this chapter provides a quick decision aid, while the interdependence framework provides a path to a systematic framework.

Our analysis utilized the frequently used and transparent method of IO analysis to look at the NCF set. By quantifying and visualizing the economic linkages between NCFs through a network, we can start to see how they are interdependent and how central NCFs exert more influence others in these interdependent networks. This analysis demonstrates how NCFs are interconnected and how this elevates the importance of specific NCFs. These connections provide a tool for more-dynamic assessments of risk to NCFs.

By analyzing the NCF-to-NCF ties through IO analysis, we could rank-order most according to their value-added multipliers, an indicator of interdependence. This provides an assessment of their relative criticality. For example, ‘Transport Materials by Pipeline’, ‘Provide Capital Markets and Investment Activities’, ‘Provide Radio Broadcast Access Network Services’, and ‘Educate and Train’ rise to the top of the list when NCFs are ranked by their economic multipliers. For example, during the COVID-19 pandemic, effects on ‘Educate and Train’ might be a particular reason for concern. The role of interdependence is also seen graphically, in which our network reveals how some NCFs (‘Exploration and Extraction of Fuels’ and ‘Store Fuel and Maintain Reserves’) are relatively central to other critical functions. This point, along with the multiplier effect of ‘Transport Materials by Pipeline’ should not be entirely surprising because petrochemicals remain centrally important to American society. Even during the COVID-19 pandemic, these NCFs have supported transportation of essential workers and products while providing essential input commodities for the production of PPE.

There are, of course, limitations to this approach. This analysis is based on pre-pandemic economic data and the pandemic has driven an economic transition that could alter these results. For example, given the shift toward a digital economy, one can expect an increasing importance of the NCFs related to telecommunications. Furthermore, substitution effects across NCFs are likely to occur. Consider, for example, a loss in the ability to transport fuel by rail, transportation by road and pipeline might provide adequate substitutes. Wireless networks might provide similar substitutes for losses in wireline access. The economic analysis presented here did not capture potential substitution effects across the NCFs where one NCF, in failure, can be replaced by another NCF (highways versus rail provide a useful example of such substitutions).

Furthermore, the IO analysis does not rank the NCFs in terms of importance to the broader social and economic system but shows the strength of economic relationships between NCFs. Future work should take the opportunity to address each of these limitations through expanded analysis and more in-depth models. For NCFs for which substitution is likely, efforts should be made to reduce interdependence. For example, ensuring that wireline and wireless communication types are not interdependent through functional relationship or colocation protects their substitutability.

We must also acknowledge the limitations of models to fully capture interdependence. In addition to an economic model, this paper advances a conceptual understanding of interdependence. Although our predominantly economic analysis provides a useful starting point, understanding how NCFs are exposed to cascading and common-cause risks can help navigate the challenges of emerging, and possibly unmodeled, risks. This challenge can be spotlighted through cases where interdependence extends to the drivers of risk. Consider, the pandemic's effects on labor: a shock to labor could result in diminished functioning across the NCFs. The shock is not only to supply. Subsequent reductions in wages could drive reductions in demand. In some cases, such as public transit, those reductions in demand risk a function's ability to operate. Furthermore, interdependence across the drivers can have geographic components. Not just because of colocation interdependence but also because processes, such as reduced wage income, could drive reduced tax income, which indirectly affects local public functions, such as education and law enforcement.

Future research should expand to other dimensions of interdependence and can do so using qualitative data where quantitative data are sparse. Interview and, in particular, expert elicitation methods should be explored in future research on interdependence to shed light noneconomic factors.

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6 Appendix

6.1 Appendix A. The National Critical Functions

Below, we reproduce the set of 55 NCFs from CISA (2020), pp. 2-7.

Table A.1. The National Critical Functions

Function	Category	Definition
Operate Core Network	Connect	Maintain and operate communications backbone infrastructure for voice, video, and data transmission that connects to users through broadcasting, cable, satellite, wireless, and wireline access networks
Provide Cable Access Network Services	Connect	Provide access to communications backbone infrastructure through fiber and coaxial cable network, supplying analog and digital video programming services, digital telephone service, and high-speed broadband services
Provide Internet Based Content, Information, and Communication Services	Connect	Produce and provide technologies, services, and infrastructure that deliver key content, information, and communications capabilities via the Internet
Provide Internet Routing, Access, and Connection Services	Connect	Provide and operate exchange and routing infrastructure, points of presence, peering points, local access services, and capabilities that enable end users to send and receive information via the Internet
Provide Positioning, Navigation, and Timing Services	Connect	Operate and maintain public and private capabilities which enable users to determine location, orientation and time
Provide Radio Broadcast Access Network Services	Connect	Operate over-the-air radio and television (TV) stations (operating at medium, very high, and ultra-high frequencies) that offer analog and digital audio and video programming services and data service
Provide Satellite Access Network Services	Connect	Provide access to core communications network via a combination of terrestrial antenna stations and platforms orbiting Earth to relay voice, video, or data signals
Provide Wireless Access Network Services	Connect	Provide access to core communications network via electromagnetic wave-based technologies, including cellular phones, wireless hot spots (Wi-Fi), personal communication services, high-frequency radio, unlicensed wireless, and other commercial and private radio services
Provide Wireline Access Network Services	Connect	Operate circuit- and packet-switched networks via copper, fiber, and coaxial transport media, including private enterprise data and telephony networks and the public switched telephone network (PSTN)
Distribute Electricity	Distribute	Maintain and operate medium- to low-voltage system to reliably supply consumer demand for electricity from the bulk electric power network
Maintain Supply Chains	Distribute	Manage and sustain the networks of assets, systems, and relationships that enable the movement of goods and services from producers to consumers
Transmit Electricity	Distribute	Maintain and operate high-voltage (>100kV) bulk electric system to reliably supply distribution network demand for electricity from generation resources
Transport Cargo and Passengers by Air	Distribute	Provide and operate aviation systems, assets, and facilities to enable a system of securely and safely conveying goods and people from place to place by air
Transport Cargo and Passengers by Rail	Distribute	Provide and operate freight and passenger railroad systems, including conveyances, infrastructure, and management systems to enable a system of securely and safely conveying goods and people from place to place by rail

Function	Category	Definition
Transport Cargo and Passengers by Road	Distribute	Provide and operate roadway systems, assets, and facilities—including commercial motor carriers and associated facilities, motor coaches, buses, and associated systems, assets, and facilities—to enable a system of securely and safely conveying goods and people from place to place by highway
Transport Cargo and Passengers by Vessel	Distribute	Provide and operate maritime systems, assets, and facilities to enable a system of securely and safely conveying goods and people from place to place by the Maritime Transportation System
Transport Materials by Pipeline	Distribute	Provide and operate systems, assets, and facilities to enable a system of securely and safely conveying materials from place to place by pipelines
Transport Passengers by Mass Transit	Distribute	Provide and operate systems, assets, and facilities to enable a system of securely and safely conveying people from place to place by roads or on fixed guideways within a specified geographic area—including transit buses, trolleybuses, monorails, heavy rail (subway), light rail, passenger rail, commuter rail, and vanpool/rideshare
Conduct Elections	Manage	Conduct elections, including managing voter registration and rolls, voting infrastructure, polling places, vote counting, and certifying and publishing election results
Develop and Maintain Public Works and Services	Manage	Design, build, and maintain infrastructure to supply government services, including systems and assets used for transportation and traffic management, water supply, waste management, recreation, and other purposes
Educate and Train	Manage	Provide education and workforce training including PreK–12, community college, university, and graduate education, technical schools, apprenticeships, non-formal education, and on-the-job training
Enforce Law	Manage	Operate Federal, State, local, tribal, territorial, and private sector assets, networks, and systems that contribute to enforcing laws, conducting criminal investigations, collecting evidence, apprehending suspects, operating the judicial system, and ensuring custody and rehabilitation of offenders
Maintain Access to Medical Records	Manage	Maintain, use, and share actionable data (including personally-identifiable information and personal health information such as care history) effectively, appropriately, bi-directionally and in a timely fashion, for patient care, billing, and operational and clinical research
Manage Hazardous Materials	Manage	Safely identify, monitor, handle, store, transport, use, and dispose of hazardous materials (including chemical, biological, radioactive, nuclear, and explosive substances) under normal operations and in response to emergencies
Manage Wastewater	Manage	Collect and treat industrial and residential wastewater to meet applicable public health and environmental standards prior to discharge into a receiving body
Operate Government	Manage	Carry out legislative, judicial, and executive government missions, including activities related to developing and enforcing codes, ordinances [sic], rules, regulations, and laws; collecting taxes and revenues; managing records, budgets, and finances; and providing public services
Perform Cyber Incident Management Capabilities	Manage	Provide security systems and services that protect critical business assets and functions, including preventive guidance, simulation, testing, and warning capabilities; operate operations response centers and teams; integrate and share information; coordinate and provide response, recovery, and reconstitution services
Prepare for and Manage Emergencies	Manage	Organize and manage resources and responsibilities for dealing with all aspects of emergencies (prevent, protect, mitigate, respond, and recover), to be resilient to and reduce the harmful effects of all hazards
Preserve Constitutional Rights	Manage	Secure the principles of freedom and independence and maintain the structures of American government through the protection of rights and processes prescribed in the U.S. Constitution

Function	Category	Definition
Protect Sensitive Information	Manage	Safeguard and ensure the integrity of information whose mishandling, spillage, corruption, or loss would harm its owner, compromise national security, or impair competitive or economic advantage
Provide and Maintain Infrastructure	Manage	Design, construct, operate, repair, survey and improve private and public infrastructure
Provide Capital Markets and Investment Activities	Manage	Issue and trade securities, including debt securities (such as bonds), equities (such as stocks), and derivatives (such as options and futures); provide advisory services and related services, such as prime brokerage; maintain operate organized markets and over-the-counter mechanisms for these instruments
Provide Consumer and Commercial Banking Services	Manage	Accept and maintain deposit accounts (e.g., checking and savings accounts) and close substitutes (e.g., short-term retail notes) from non-financial intermediaries
Provide Funding and Liquidity Services	Manage	Provide funding to non-financial counterparties, such as corporate or retail customers, including individual consumers
Provide Identity Management and Associated Trust Support Services	Manage	Produce and provide technologies, services, and infrastructure to ensure the identity of, authenticate, and authorize entities and ensure confidentiality, integrity, and availability of devices, services, data, and transactions
Provide Insurance Services	Manage	Operate systems and markets to transfer financial risks among parties through contractual relationships, including products for individuals, corporations, and public-sector entities
Provide Medical Care	Manage	Ensure the provision of healthcare services
Provide Payment, Clearing, and Settlement Services	Manage	Carry out processes required for the exchange of assets, including payment (transfer of funds between or among participants), clearing (transmitting, reconciling, and confirming transactions prior to settlement), and settlement (transfer of ownership and payments)
Provide Public Safety	Manage	Provide public services—to include police, fire, and emergency medical services—to ensure the safety and security of communities, businesses and populations
Provide Wholesale Funding	Manage	Maintain processes for lending and borrowing among financial services sector parties
Store Fuel and Maintain Reserves	Manage	Store energetic materials (including fossil and nuclear fuels) to reliably meet operational and strategic demands
Support Community Health	Manage	Conduct epidemiologic surveillance, environmental health, migrant and shelter operations, food establishment inspections, and other community-based public health activities
Exploration and Extraction of Fuels	Supply	Identify resources and collect energetic materials (including fossil fuels, nuclear materials, and others)
Fuel Refining and Processing Fuels	Supply	Transform raw energetic materials into consumer fuels (e.g., crude cracking, gas separation, and uranium enrichment)
Generate Electricity	Supply	Produce electricity from a variety of primary energy sources (including fossil fuels, nuclear materials, and renewables) to reliably meet demand
Manufacture Equipment	Supply	Fabricate and assemble components to produce tangible property
Produce and Provide Agricultural Products and Services	Supply	Grow and harvest plant and animal commodities (including crops, livestock, dairy, aquaculture, and timber) and produce inputs required to support agricultural production (such as fertilizers, pesticides, animal food, crop seeds, and veterinary services)
Produce and Provide Human and Animal Food Products and Services	Supply	Produce food products from raw agricultural commodities and provide to final consumers (including processing, packaging and production, product storage as well as retail and food service)
Produce Chemicals	Supply	Manufacture basic chemicals from raw organic and inorganic materials and manufacture intermediate and final products from basic chemicals

Function	Category	Definition
Provide Metals and Materials	Supply	Manufacture iron, steel, and ferro-alloy products; alumina and aluminum products; non-ferrous metals; and other materials as primary components for other industries
Provide Housing	Supply	Construct and/or provide safe and secure permanent or temporary shelter for people (includes physical construction and emergency sheltering)
Provide Information Technology Products and Services	Supply	Design, develop, and distribute hardware and software products and services (including security and support services) necessary to maintain or reconstitute networks and associated services
Provide Materiel and Operational Support to Defense	Supply	Develop, produce, and sustain defense systems and components and provide support to defense operations
Research and Development	Supply	Conduct basic research, innovate, test, and introduce new products and services or improve existing products and services
Supply Water	Supply	Maintain availability of water (raw and treated)

6.2 Appendix B. NCF Interdependence Tables

Table B.1 shows the multiplier or multipliers we used to determine value added for each NCF for specific types of events. Notably, the NCFs are of varying levels of specificity in economic terms. Although some refer to very specific economic sectors (closely following the sectors identified by NAICS codes) others are broader. In most cases, an NCF can be assigned to a single sector; however, in some, they cannot. Each of the NCFs ‘Develop and Maintain Public Works and Services’, ‘Generate Electricity’, ‘Produce Chemicals’, ‘Provide Metals and Materials’, and ‘Provide Information Technology Products and Services’, for example, applies to a set of economic sectors and consequently can carry a range of economic multipliers. Each of the NCFs ‘Conduct Elections’, ‘Enforce Law’, ‘Perform Cyber Incident Management Capabilities’, ‘Prepare for and Manage Emergencies’, ‘Preserve Constitutional Rights’, and ‘Provide Public Safety’ broadly refers to activities of federal, state, and local government, so each carries an economic multiplier of 1 in Figure 2 and Table B.1. Finally, each of the NCFs at the bottom of Figure 2 – ‘Maintain Supply Chains’, ‘Operate Government’, ‘Protect Sensitive Information’, ‘Provide and Maintain Infrastructure’, ‘Manufacture Equipment’, ‘Produce and Provide Agricultural Products and Services’, ‘Produce and Provide Human and Animal Food Products and Services’, ‘Provide Housing’, and ‘Provide Materiel and Operational Support to Defense’ – is each too broad to be considered through analysis of economic interdependence.

Table B.1. Estimated NCF Interdependence Multiplier Effect

NCF	IMPLAN Sector	Value-Added Multiplier
Operate Core Network	430	1.51
Provide Cable Access Network Services	426	1.28
Provide Internet Based Content, Information, and Communication Services	432	1.52
Provide Internet Routing Access, and Connection Services	427	1.29

NCF	IMPLAN Sector	Value-Added Multiplier
Provide Positioning, Navigation, and Timing Services	429	1.62
Provide Radio Broadcast Access Network Services	425	1.70
Provide Satellite Access Network Services	429	1.62
Provide Wireless Access Network Services	428	1.17
Provide Wireline Access Network Services	427	1.29
Distribute Electricity	49	1.18
Maintain Supply Chains	Too broad	
Transmit Electricity	49	1.18
Transport Cargo and Passengers by Air	408	1.22
Transport Cargo and Passengers by Rail	409	1.37
Transport Cargo and Passengers by Road	411	1.43
Transport Cargo and Passengers by Vessel	410	1.23
Transport Materials by Pipeline	413	1.81
Transport Passengers by Mass Transit	412	1.47
Conduct Elections	State and local government	1.00
Develop and Maintain Public Works and Services	519, 522, 525, 526	1.2–1.4
Educate and Train	474	1.64
Enforce Law	State and local government	1.00
Maintain Access to Medical Records	475–484	1.50
Manage Hazardous Materials	471	1.36
Manage Wastewater	51	1.43
Operate Government	Too broad	
Perform Cyber Incident Management Capabilities	State and local government	1.00
Prepare for and Manage Emergencies	State and local government	1.00
Preserve Constitutional Rights	Federal government	1.00
Protect Sensitive Information	Too broad	
Provide and Maintain Infrastructure	Too broad	
Provide Capital Markets and Investment Activities	435–436	1.80
Provide Consumer and Commercial Banking Services	433–434	1.63
Provide Funding and Liquidity Services	433–434	1.63
Provide Identity Management and Associated Trust Support Services	439	1.43
Provide Insurance Services	437	1.37
Provide Medical Care	475–484	1.50
Provide Payment, Clearing, and Settlement Services	433–434	1.63
Provide Public Safety	State and local government	1.00
Provide Wholesale Funding	433–436	1.60
Store Fuel and Maintain Reserves	156	0.91

NCF	IMPLAN Sector	Value-Added Multiplier
Support Community Health	483	1.57
Exploration and Extraction of Fuels	20	1.49
Fuel Refining and Processing Fuels	156	0.91
Generate Electricity	41–48	1.1–1.4
Manufacture Equipment	Too broad	
Produce and Provide Agricultural Products and Services	Too broad	
Produce and Provide Human and Animal Food Products and Services	Too broad	
Produce Chemicals	161–166	1–1.2
Provide Metals and Materials	227–231	0.85–1.2
Provide Housing	Too broad	
Provide Information Technology Products and Services	430–432	1.51
Provide Materiel and Operational Support to Defense	DIB	
Research and Development	456	1.52
Supply Water	51	1.43

SOURCE: IMPLAN Group (2020) data.

NOTE: DIB = defense industrial base. For most single NCFs, we were able to identify single IMPLAN sectors. However, we assigned some NCFs with broad categories to multiple IMPLAN sectors or the category of “government.” We were unable to identify sector groupings for some NCFs because they were too broad to constrain as single or multiple sectors. We note that, in IO analyses to determine a unitless value-added multiplier for each NCF, NCFs are of varying levels of economic specificity. An NCF too broad to be assigned to a single sector might carry a range of economic multipliers aligned with multiple sectors, and multiple IMPLAN sectors might also be converted into single value-added multipliers.

Table B.2 illustrates the level of interdependence between each pair of NCFs, and Table B.3 lists NCF abbreviations used in Table B.2.

Table B.2. NCF Interdependence Matrix

	Extraction of Fuels	Generate Electricity	Distribute/Transmit Electricity	Water/Wastewater	Store/Refine Fuel	Produce Chemicals	Produce Metals and Materials	Air Transport	Rail Transport	Vessel Transport	Road Transport	Mass Transit	Pipeline	IT Products and Services	Radio Broadcasts	Cable Access	Internet Routing	Wireless/Satellite Access	GPS	Operate Core Network	Internet Content	Consumer Banking and Settlement	Funding and Liquidity	Wholesale/Capital Markets	Insurance	Identity Management and Trust Support Services	Research and Development	Hazardous Waste	Educate and Train	Medical Records	Medical Care	Community Health	Public Works	NCF Multiplier	
Extraction of Fuels	1.042	0.225	0.093	0.008	0.701	0.361	0.048	0.056	0.043	0.077	0.056	0.025	0.039	0.004	0.008	0.005	0.006	0.009	0.007	0.014	0.010	0.004	0.009	0.006	0.004	0.007	0.007	0.013	0.008	0.007	0.009	0.009	0.038	2.959	
Generate Electricity	0.004	1.006	0.379	0.005	0.005	0.019	0.029	0.004	0.005	0.011	0.007	0.007	0.005	0.003	0.007	0.004	0.005	0.008	0.006	0.012	0.008	0.003	0.006	0.005	0.003	0.006	0.007	0.007	0.006	0.006	0.008	0.008	0.008	0.008	1.611
Distribute/Transmit Electricity	0.009	0.013	1.011	0.013	0.012	0.045	0.067	0.010	0.011	0.025	0.016	0.017	0.012	0.006	0.017	0.009	0.013	0.019	0.013	0.028	0.018	0.006	0.015	0.012	0.008	0.013	0.016	0.015	0.013	0.013	0.018	0.019	0.018	1.552	
Water/Wastewater	0.001	0.003	0.002	1.002	0.001	0.003	0.003	0.001	0.001	0.004	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.002	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.002	1.050	
Store/Refine Fuel	0.007	0.025	0.018	0.007	1.025	0.256	0.040	0.070	0.054	0.093	0.069	0.029	0.011	0.003	0.007	0.005	0.005	0.007	0.007	0.013	0.010	0.003	0.009	0.006	0.004	0.007	0.007	0.013	0.008	0.006	0.008	0.008	0.019	1.857	
Produce Chemicals	0.006	0.003	0.003	0.001	0.018	1.843	0.008	0.002	0.002	0.004	0.003	0.002	0.002	0.001	0.001	0.001	0.001	0.003	0.001	0.003	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.001	0.002	0.002	0.002	0.003	1.931
Produce Metals and Materials	0.001	0.001	0.001	0.000	0.001	0.002	1.080	0.001	0.002	0.003	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.002	0.001	0.000	0.001	0.000	0.000	0.001	0.001	0.004	0.001	0.001	0.001	0.001	0.002	1.114	
Air Transport	0.005	0.007	0.006	0.005	0.006	0.020	0.020	1.006	0.008	0.014	0.017	0.008	0.008	0.006	0.010	0.007	0.007	0.010	0.011	0.027	0.017	0.006	0.016	0.008	0.006	0.006	0.012	0.009	0.014	0.009	0.009	0.008	0.008	0.010	1.343
Rail Transport	0.002	0.032	0.015	0.003	0.005	0.087	0.151	0.002	1.005	0.005	0.016	0.003	0.003	0.001	0.003	0.002	0.002	0.004	0.002	0.005	0.003	0.001	0.003	0.002	0.001	0.002	0.003	0.004	0.002	0.002	0.003	0.003	0.004	1.380	
Vessel Transport	0.001	0.001	0.001	0.001	0.001	0.004	0.010	0.001	0.001	1.001	0.001	0.001	0.002	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.000	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	1.041	
Road Transport	0.007	0.010	0.008	0.007	0.021	0.061	0.085	0.011	0.014	0.022	1.028	0.012	0.011	0.005	0.011	0.008	0.008	0.014	0.010	0.020	0.016	0.005	0.011	0.009	0.006	0.010	0.010	0.015	0.011	0.010	0.012	0.011	0.017	1.518	
Mass Transit	0.002	0.003	0.002	0.002	0.002	0.005	0.007	0.002	0.006	0.004	0.004	1.003	0.003	0.002	0.004	0.003	0.003	0.004	0.004	0.013	0.006	0.003	0.007	0.003	0.003	0.005	0.004	0.005	0.004	0.005	0.004	0.005	0.004	1.134	
Pipeline	0.020	0.053	0.026	0.002	0.064	0.048	0.013	0.009	0.007	0.013	0.009	0.004	1.004	0.001	0.002	0.001	0.001	0.002	0.002	0.003	0.002	0.001	0.002	0.001	0.001	0.001	0.002	0.002	0.003	0.002	0.002	0.002	0.017	1.322	
IT Products and Services	0.003	0.004	0.003	0.003	0.004	0.007	0.009	0.004	0.005	0.006	0.006	0.005	0.005	0.005	1.072	0.006	0.005	0.005	0.006	0.007	0.025	0.015	0.003	0.007	0.006	0.004	0.008	0.006	0.005	0.008	0.006	0.005	0.007	1.277	
Radio Broadcasts	0.003	0.004	0.003	0.002	0.004	0.009	0.011	0.004	0.006	0.017	0.007	0.006	0.006	1.126	0.016	0.012	0.033	0.010	0.014	0.044	0.006	0.012	0.005	0.005	0.009	0.006	0.006	0.006	0.006	0.006	0.005	0.008	1.425		
Cable Access	0.002	0.003	0.002	0.002	0.002	0.006	0.007	0.003	0.003	0.009	0.004	0.004	0.003	0.003	0.037	1.162	0.102	0.028	0.014	0.010	0.021	0.003	0.007	0.004	0.003	0.006	0.004	0.004	0.006	0.004	0.004	0.003	0.005	1.479	
Internet Routing	0.009	0.010	0.009	0.009	0.011	0.021	0.027	0.013	0.013	0.028	0.020	0.020	0.014	0.009	0.022	0.012	1.122	0.165	0.116	0.051	0.037	0.008	0.024	0.018	0.011	0.022	0.015	0.016	0.021	0.016	0.018	0.014	0.018	1.942	
Wireless/Satellite Access	0.009	0.009	0.008	0.007	0.010	0.019	0.025	0.011	0.012	0.024	0.018	0.017	0.013	0.008	0.018	0.011	0.032	1.080	0.042	0.041	0.022	0.008	0.022	0.016	0.010	0.018	0.014	0.015	0.017	0.015	0.014	0.016	1.617		
GPS	0.000	0.001	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.003	0.004	1.004	0.003	0.002	0.000	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	1.041	
Operate Core Network	0.002	0.005	0.004	0.002	0.003	0.007	0.011	0.006	0.005	0.007	0.005	0.005	0.004	0.004	0.005	0.006	0.006	0.008	0.005	1.025	0.017	0.007	0.008	0.005	0.004	0.030	0.006	0.008	0.005	0.004	0.007	0.004	0.010	1.240	
Internet Content	0.003	0.005	0.004	0.003	0.004	0.010	0.012	0.005	0.006	0.016	0.007	0.007	0.005	0.007	0.023	0.012	0.010	0.030	0.011	0.018	1.083	0.006	0.012	0.006	0.005	0.011	0.009	0.008	0.028	0.007	0.007	0.006	0.011	1.394	
Consumer Banking and Settlement	0.027	0.044	0.036	0.030	0.032	0.070	0.093	0.038	0.054	0.074	0.070	0.067	0.041	0.026	0.047	0.035	0.036	0.053	0.044	0.095	0.057	1.076	0.123	0.050	0.041	0.137	0.064	0.045	0.049	0.047	0.046	0.048	0.106	2.901	
Funding and Liquidity	0.007	0.010	0.008	0.007	0.009	0.023	0.031	0.010	0.050	0.018	0.022	0.037	0.011	0.006	0.014	0.010	0.009	0.011	0.015	0.021	0.016	0.020	1.046	0.016	0.009	0.032	0.011	0.014	0.013	0.012	0.014	0.011	0.022	1.565	
Wholesale/Capital Markets	0.006	0.010	0.008	0.006	0.008	0.016	0.037	0.009	0.021	0.071	0.016	0.018	0.010	0.006	0.010	0.010	0.008	0.010	0.009	0.017	0.012	0.034	0.033	1.035	0.013	0.156	0.011	0.011	0.012	0.010	0.015	0.011	0.022	1.679	
Insurance	0.022	0.023	0.020	0.019	0.026	0.054	0.061	0.026	0.028	0.068	0.080	0.058	0.033	0.018	0.038	0.025	0.024	0.028	0.040	0.055	0.048	0.018	0.055	0.035	1.100	0.045	0.034	0.051	0.039	0.058	0.078	0.040	0.058	2.405	
Identity Management and Trust Support Services	0.006	0.005	0.005	0.004	0.006	0.010	0.013	0.006	0.007	0.009	0.009	0.008	0.008	0.004	0.009	0.005	0.006	0.006	0.008	0.011	0.010	0.005	0.011	0.009	0.012	1.025	0.008	0.007	0.008	0.008	0.009	0.007	0.010	1.277	
Research and Development	0.000	0.002	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.000	0.001	0.001	0.001	0.001	0.001	0.000	0.001	0.001	0.000	0.001	1.045	0.001	0.001	0.001	0.001	0.001	0.001	1.069	
Hazardous Waste	0.003	0.004	0.003	0.003	0.004	0.019	0.032	0.005	0.004	0.087	0.007	0.030	0.004	0.002	0.004	0.003	0.003	0.005	0.004	0.007	0.006	0.002	0.004	0.004	0.003	0.004	0.005	1.100	0.007	0.004	0.006	0.007	0.018	1.401	
Educate and Train	0.003	0.003	0.002	0.002	0.003	0.005	0.006	0.003	0.003	0.004	0.004	0.004	0.004	0.002	0.005	0.003	0.003	0.003	0.004	0.005	0.005	0.002	0.004	0.004	0.002	0.004	0.004	0.003	1.017	0.004	0.004	0.003	0.004	1.129	
Medical Records	0.020	0.019	0.017	0.016	0.022	0.036	0.045	0.020	0.023	0.031	0.032	0.026	0.030	0.015	0.034	0.019	0.019	0.020	0.029	0.040	0.035	0.014	0.032	0.029	0.018	0.028	0.027	0.025	0.028	1.028	0.028	0.025	0.030	1.863	
Medical Care	0.030	0.029	0.026	0.024	0.033	0.055	0.069	0.030	0.035	0.046	0.048	0.039	0.045	0.022	0.051	0.029	0.029	0.031	0.044	0.060	0.053	0													

Table B.3. Abbreviated NCF Names Used in Table B.2

Abbreviated NCF Name	Full NCF Name
Air Transport	Transport Cargo and Passengers by Air
Cable Access	Provide Cable Access Network Services
Cable Access	Provide Wireline Access Network Services
	Support Community Health
Consumer Banking and Settlement	Provide Consumer and Commercial Banking Services
Consumer Banking and Settlement	Provide Payment, Clearing, and Settlement Services
Distribute/Transmit Electricity	Distribute Electricity
Distribute/Transmit Electricity	Transmit Electricity
	Educate and Train
Extraction of Fuels	Exploration and Extraction of Fuels
Funding and Liquidity	Provide Funding and Liquidity Services
Generate Electricity	Generate Electricity
GPS	Provide Positioning, Navigation, and Timing Services
Hazardous Waste	Manage Hazardous Materials
Identity Management and Trust Support Services	Provide Identity Management and Associated Trust Support Services
Insurance	Provide Insurance Services
Internet Content	Provide Internet Based Content, Information, and Communication Services
Internet Routing	Provide Internet Routing, Access, and Connection Services
IT Products and Services	Provide Information Technology Products and Services
Mass Transit	Transport Passengers by Mass Transit
	Provide Medical Care
Medical Records	Maintain Access to Medical Records
Operate Core Network	Operate Core Network
Pipeline	Transport Materials by Pipeline
Produce Chemicals	Produce Chemicals
	Provide Metals and Materials
Public Works	Develop and Maintain Public Works and Services
Radio Broadcasts	Provide Radio Broadcast Access Network Services
Rail Transport	Transport Cargo and Passengers by Rail
Research and Development	Research and Development
Road Transport	Transport Cargo and Passengers by Road
Store/Refine Fuel	Fuel Refining and Processing Fuels
	Store Fuel and Maintain Reserves
Vessel Transport	Transport Cargo and Passengers by Vessel
Water/Wastewater	Manage Wastewater
Water/Wastewater	Supply Water
Wholesale/Capital Markets	Provide Wholesale Funding
Wholesale/Capital Markets	Provide Capital Markets and Investment Activities
Wireless/Satellite Access	Provide Wireless Access Network Services
Wireless/Satellite Access	Provide Satellite Access Network Services