

## Supplementary Information

### System approach for characterizing and evaluating factors for occupational health impacts due to nonfatal injuries and illnesses for the use in life cycle assessment

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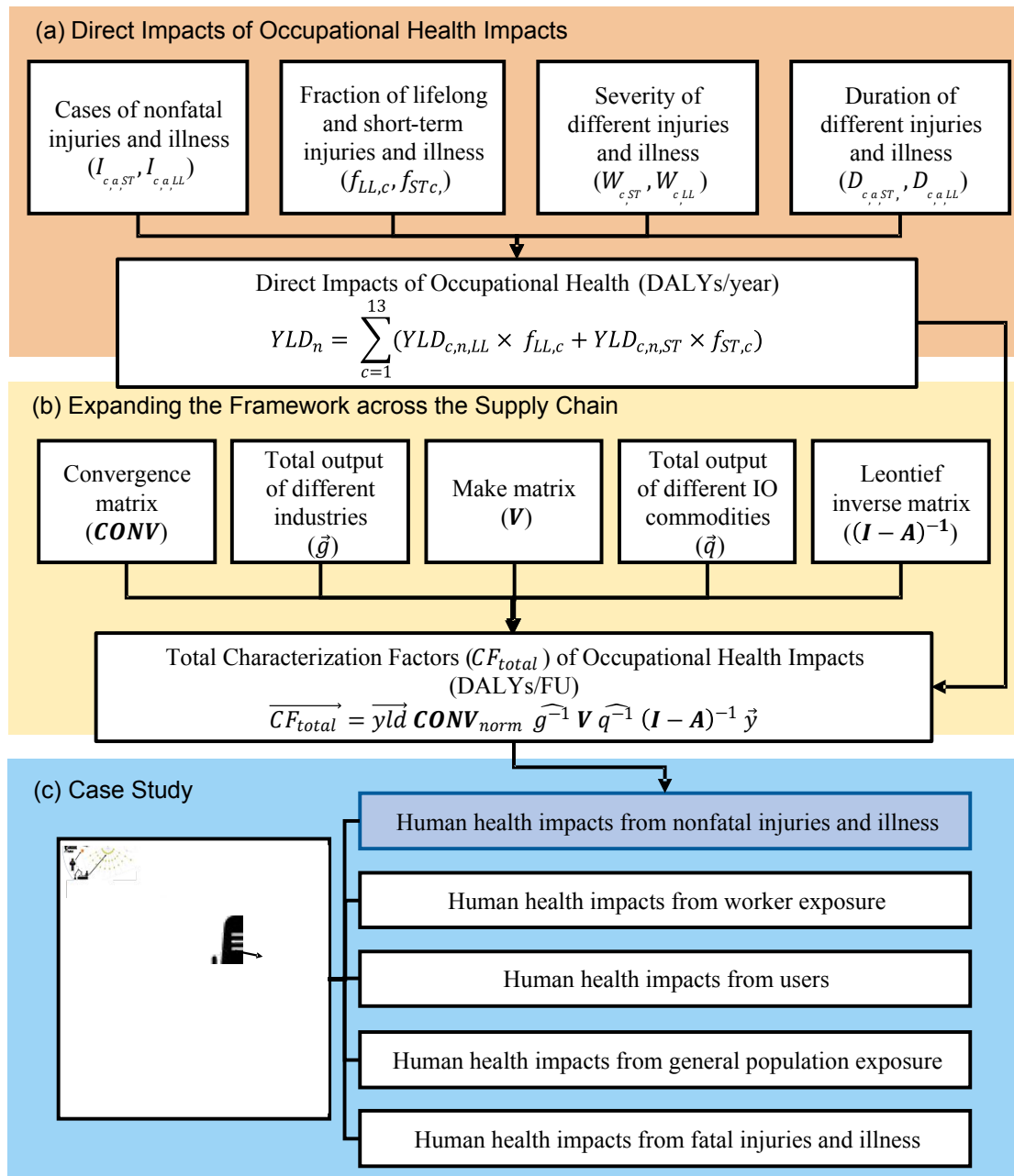
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## Section S1: Workflow of the study



**Figure S1.** The workflow of the study. DALYs represents disability-adjusted life years. (a) the calculation of direct impacts of work environment human health through their produce process; (b) the calculation of total characterization factors of occupational health impacts across the entire supply chain; (c) a case study of an office chair to compare occupational health impacts with other human health impacts

## **Section S2: Additional notes on methods**

### **Section S2.1: Further explanations on data source**

Injury statistics by industry as represented by NACIS codes from 2014 to 2018 provided by the U.S. Bureau of Labor Statistics were used in this study, which covers 13 workplace injuries and all 1067 NACIS codes representing Class 6 industries<sup>1</sup>; these data provide the specific number of different workplace injuries per year in these industries as well as the duration of different workplace injuries. In turn, the Global Burden of Disease provides data needed for this study including, but not limited to, the proportion of different diseases that produce lifetime (or short-term) effects, the duration of different diseases, and the severity of different diseases.<sup>2-7</sup> The US Environmentally-Extended Input-Output Models (USEEIO v2.0)<sup>8</sup>, calculated by the US Bureau of Economic Analysis based on 2012 data, are the primary economic data for this study (including total production, total output in US dollars for the corresponding commodities in each industry, production matrices that allow the conversion of IO industries into IO commodities, and direct production matrices. The USEEIO is the source of the main economic data for this study (including total production, total output of each industry in dollar terms, production matrix that converts IO industries into IO commodities, and direct input coefficient matrix) (Table S1-4).

### **Section S2.2: Allocation**

Due to an inherent flaw in the data used, not all 6-digit industries have corresponding injury data, but all 6-digit industries are needed in the convergence matrix, so the data need to be filled in. Since only 2-digit industries in the 6-digit classification system cover all 6-digit industries, it was decided to use the injury and illness data from 2-digit industries to assign the 6-digit industries with missing data covered by them. The number of injuries and illnesses for all 6-digit industries was estimated by first deducting the existing 6-digit industry data from the injury and illness data for 2-digit industries, and then equally distributing the remaining number of injuries and illnesses to all corresponding 6-digit industries (including 6-digit industries with data).

**Table S1. Variable names, symbols and their sources**

<b>Variable Name</b>	<b>Description</b>	<b>Symbol</b>	<b>Source</b>
Severity	the severity of short-term (ST) or lifelong (LL) injuries and illness indicated by each of the natural codes (c)	$W_{c,ST}$ $W_{c,LL}$	Report from James et al. <sup>9</sup> Global Burden of Disease report 2013 <sup>6</sup> & 2017
Cases	different occupational injuries and illnesses (c) in each age group (a) for short-term (ST) or lifetime (LL) nonfatal injuries and illnesses	$I_{c,a,ST}$ $I_{c,a,LL}$	U.S. Bureau of Labor Statistics (2014-2018) <sup>1</sup>
Short-term duration	duration of each short-term (ST) injury or illness (c) in each age group (a)	$D_{c,a,ST}$	Global Burden of Disease report 1996 <sup>4</sup> & 2013 <sup>6</sup>
Lifelong duration	duration of lifelong (LL) injuries and illnesses (c) in each age group (a)	$D_{c,a,LL}$	
Short-long split coefficient	Split injuries into lifelong and short-term	$f_{LL}$ $f_{ST}$	
Conversion matrix	turn NAICS code into EIO code	<b><i>CONV</i></b>	
Total output of industries	inverse diagonal matrix of the total output of the different industries	$\vec{g}$	
Make matrix	IO industries as rows and IO goods as columns	<b><i>V</i></b>	
Total output of commodities	inverse diagonal matrix based on the total output of commodities in different industries	$\vec{q}$	US Environmentally-Extended Input-Output Models (USEEIO v2.0) <sup>8</sup> (developed based on data from U.S. Bureau of Economic Analysis)
Leontief inverse matrix	represent the total production of different industries required to produce one dollar of that type of good	$(\mathbf{I} - \mathbf{A})^{-1}$	
Final demand vector	represent each good in the manufacturing stage in \$ per good	$\vec{y}$	

**Table S2. Specific sources of severity weight and short-term duration**

Type of injuries or illnesses	Life-long severity weight ( $W_{c,LL}$ ), average age	Short-term severity weight, ( $W_{c,ST}$ ), average age	Short-term duration, ( $D_{c,a,ST}$ ), average age
Sprains, strains, tears	-	James et al. 2020	BLS 2015
Fractures	GBD, 2013	James et al. 2020	GBD 1996
Cuts, lacerations	-	James et al. 2020	GBD 1996
Puncture wounds, except gunshot wounds	-	James et al. 2020	GBD 1996
Bruises, contusions	-	James et al. 2020	BLS 2015
Heat burns	GBD, 2013	James et al. 2020	GBD 1996
Chemical burns	GBD, 2013	James et al. 2020	GBD 1996
Amputations	GBD, 2010	-	BLS 2015
Carpal tunnel syndrome	GBD, 2013	James et al. 2020	BLS 2015
Tendonitis	GBD, 2013	-	BLS 2015
Multiple traumatic injuries and disorders	GBD, 2013	James et al. 2020	GBD 1996
Soreness, pain	-	Scanlon et al.	BLS 2015
Unspecified nonfatal injuries	Weighted average of all other lifelong injuries depending on the number of injuries reported in 2015-2018[BLS]	Weighted average of all other short-term injuries depending on the number of injuries reported in 2015-2018[BLS]	Weighted average of all other short-term injuries depending on the number of injuries reported in 2015-2018[BLS]

**Table S3. Specific values of severity weight and short-term duration**

Type of injuries or illnesses	Life-long severity weight ( $W_{c,LL}$ ), average age	Short-term severity weight, ( $W_{c,ST}$ ), average age	Short-term duration, ( $D_{c,a,ST}$ ), average age
Sprains, strains, tears	0.000	0.0075	0.038
Fractures	0.066	0.1081	0.108
Cuts, lacerations	0.000	0.0058	0.024
Puncture wounds, except gunshot wounds	0.000	0.0058	0.024
Bruises, contusions	0.000	0.0075	0.016
Heat burns	0.076	0.2772	0.214
Chemical burns	0.076	0.2772	0.214
Amputations	0.131	0.0000	0.104
Carpal tunnel syndrome	0.113	0.0638	0.112
Tendonitis	0.187	0.0000	0.056
Multiple traumatic injuries and disorders	0.252	0.1392	0.034
Soreness, pain	0.000	0.061	0.028
Unspecified nonfatal injuries	0.105	0.0388	0.044

**Table S4. Specific values and source of the fraction of cases that result in short-term or lifelong health outcomes**

Types of injury or illnesses	Baseline		Sensitivity analysis		Original Source in Scanlon et al. <sup>10</sup>
	Lifelong	Short-term	Lifelong	Short-term	
Sprains, strains, tears	0%	100%	1%	99%	021 Sprains- strains-tears
Fractures	2%	98%	3%	97%	012 Fractures
Cuts, lacerations	0%	100%	1%	99%	034 Cuts- lacerations
Puncture wounds	0%	100%	1%	99%	037 Punctures- except bites
Bruises, contusions	0%	100%	1%	99%	043 Bruises- contusions
Heat burns	50%	50%	51%	49%	053 Heat burns- scalds
Chemical burns	50%	50%	51%	49%	051 Chemical burns
Amputations	100%	0%	100%	0%	031 Amputations
Carpal tunnel syndrome	50%	50%	51%	49%	124 Disorders of the peripheral nervous system
Tendonitis	100%	0%	99%	1%	173 Rheumatism- except the back
Multiple traumatic injuries	40%	60%	41%	61%	080 Multiple traumatic injuries and disorders- unspecified
Soreness, pain	20%	80%	21%	79%	097 Nonspecified injuries and disorders (adjusted*)
Unspecified nonfatal injuries	25%	75%	26%	74%	9999 Nonclassifiable (adjusted**)

Note: Data marked with '(adjusted)' is not the same as the original ones

\* Adjusted because these two categories do not correspond perfectly and are adjusted after expert opinion.

\*\* Adjusted because it is a weighted average of all other diseases by number of cases.

### Section S2.3: Nomenclature used in this study

This section details the different nomenclature used in the study to avoid confusions (Table S5). Corresponding formulae for some specific terms are also provided.

**Table S5. Descriptions of nomenclature used in this study**

Nomenclature	Description
Direct impacts	Direct occupational impacts in a specific sector. These are based on the reported BLS cases (converted to DALYs).
Supply chain impacts	Indirect occupational impacts in the supply chain of a specific sector. These are based on the IO, inter-sector demand from the BEA and the direct impacts noted above. For example, if sector A has demand for sector B of X (\$/\$), and sector B has impacts of Y/\$, then A has indirect impacts in B of X*Y.
Supply chain impact outside the producer sector	Indirect occupational impacts occurred in other sectors of the supply chain
Supply chain impact in producer sector	Indirect occupational impacts occurred in the producer sector due to the need of supply chain
Total impacts	The sum of direct impacts and supply chain impacts
Total output	The sum of the values of final goods and services produced by the industry. This value is used to calculate direct impact factors occurred in a specific sector. For example, “ <i>Other real estate</i> ” has one of the highest outputs (889.33 billion \$), while “ <i>Doll, toy, and game manufacturing</i> ” has one of the lowest (1.8 billion \$).
Final demand	The value of purchases made by final users (Final demand = total output - intermediate output used in intra-industries). This value is used to calculate the direct CFs, supply chain CFs, and total CFs. For example, “ <i>Owner-occupied housing</i> ” has one of the highest demands (1276.28 billion \$), while “ <i>Lime and gypsum product manufacturing</i> ” has one of the lowest (0.014 billion \$).
Direct impact factors	Characterization factors (CFs) for direct occupational health impacts occurred in a specific sector (Direct impact factors = direct impacts/total output, DALYs/\$ <sub>output</sub> )
Direct CFs ( $CF_D$ )	Characterization factors (CFs) for direct occupational health impacts occurred in a specific sector (Direct CFs = direct impacts/final demand, DALYs/\$ <sub>demand</sub> )
Supply chain CFs ( $CF_{SC}$ )	Characterization factors (CFs) for indirect occupational health impacts occurred in a specific sector (Supply chain CFs = supply chain impacts/final demand, DALYs/\$ <sub>demand</sub> )
Total CFs ( $CF_{total}$ )	The sum of $CF_D$ and $CF_{SC}$ (DALYs/\$ <sub>demand</sub> )

The total demand can be calculated as follow:

$$Total\ demand = (\mathbf{I} - \mathbf{A})^{-1} \vec{y} = \vec{y} + (\mathbf{I} - \mathbf{A})^{-1} \mathbf{A} \vec{y} \quad (\text{Eq. S1})$$

where  $\mathbf{I}$  represents the identity matrix and  $\mathbf{A}$  represents the direct requirement matrix.  $\vec{y}$  is the direct demand per FU to the manufacturer of a product, then  $\mathbf{A} \vec{y}$  the indirect demand per FU in the supply chain of the product manufacturer. Eq. S1 shows that the



total demand is the sum of the direct demand and indirect demand. Joining Eq. 8, Eq. 9, and Eq. 11 (in the manuscript), we can get:

$$CF_D = \overline{y} \overline{ld} \mathbf{B} \vec{y} \quad (\text{Eq. S2})$$

$$CF_{SC} = \overline{y} \overline{ld} \mathbf{B} (\mathbf{I} - \mathbf{A})^{-1} \mathbf{A} \vec{y} \quad (\text{Eq. S3})$$

$$CF_{total} = CF_D + CF_{SC} \quad (\text{Eq. S4})$$

where  $\mathbf{B}$  is an interference matrix to combine direct impact factors for occupational health impacts with IO analysis (i.e., indirect occupational health impacts) to analyze product life-cycle impacts covering all supply chains in an economic system. And

$(\mathbf{I} - \mathbf{A})^{-1}$  is the Leontief inverse matrix and each column of the matrix represents the total production of different industries required to produce one dollar of that good, and the units of its rows are all in dollars (\$/\$). The vector  $\vec{y}$  is the final demand vector for each good in the manufacturing stage in \$ per good (\$/functional unit).

#### **Section S2.4: Conversion from NAICE code to EIO code**

Since the injury data provided by the U.S. Bureau of Labor Statistics are classified according to the NAICS code, the matrix related to the input-output analysis to be used in subsequent calculations uses the EIO code classification. Therefore, we need to use a matrix to convert the data of these two classifications. We correspond the industries classified by NAICS code to the industries classified by EIO code and find that they can be divided into two major categories. One is that NAICS code corresponds to more than one EIO code, and the other is that NAICS code corresponds to only one EIO code (EIO code can correspond to more than one NAICS code). The former case is weighted according to the total product supply of different industries corresponding to EIO code, while the latter can directly correspond one by one.

#### **Section S2.5: Structural Path Analysis (SPA)**

The Leontief inverse matrix of the input-output model reflects the cumulative effect of industry chain paths and provides a basis for extracting industry chain paths within the economic system. By combining the input-output model with structural path analysis, the main industry chain paths leading to environmental stress in the economic system can be extracted. For example, the chain path "agriculture-food-restaurant-consumer" indicates that the consumption in restaurants drives food production, and food production further drives environmental stress in the agricultural sectors.<sup>11</sup> With

the Taylor expansion, the Leontief inverse matrix can be written as follows (Eq. S7 and Eq. S8).

$$(\mathbf{I} - \mathbf{A})^{-1} = \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \mathbf{A}^3 + \dots \quad (\text{Eq. S7})$$

$$e = f\mathbf{y} + f\mathbf{A}\mathbf{y} + f\mathbf{A}^2\mathbf{y} + f\mathbf{A}^3\mathbf{y} + \dots \quad (\text{Eq. S8})$$

where  $\mathbf{I}$  represents identity matrix and  $\mathbf{A}$  represents direct requirement matrix. Each term on the right-hand side shows the workplace occupational health impact for a specific production layer. SPA extracts the individual supply chain pathways that contribute to the workplace occupational health impact for each production layer. Suppose a supply chain starts in department  $i$ , passes through  $r$  departments ( $k_1, k_2, \dots, k_r$ ) and ends in department  $j$ . The emissions from this supply chain pathway (i.e., the emissions generated in sector  $i$ , driven by the final demand for the product in sector  $j$ ) are estimated by the formula as follows (Eq. S9).

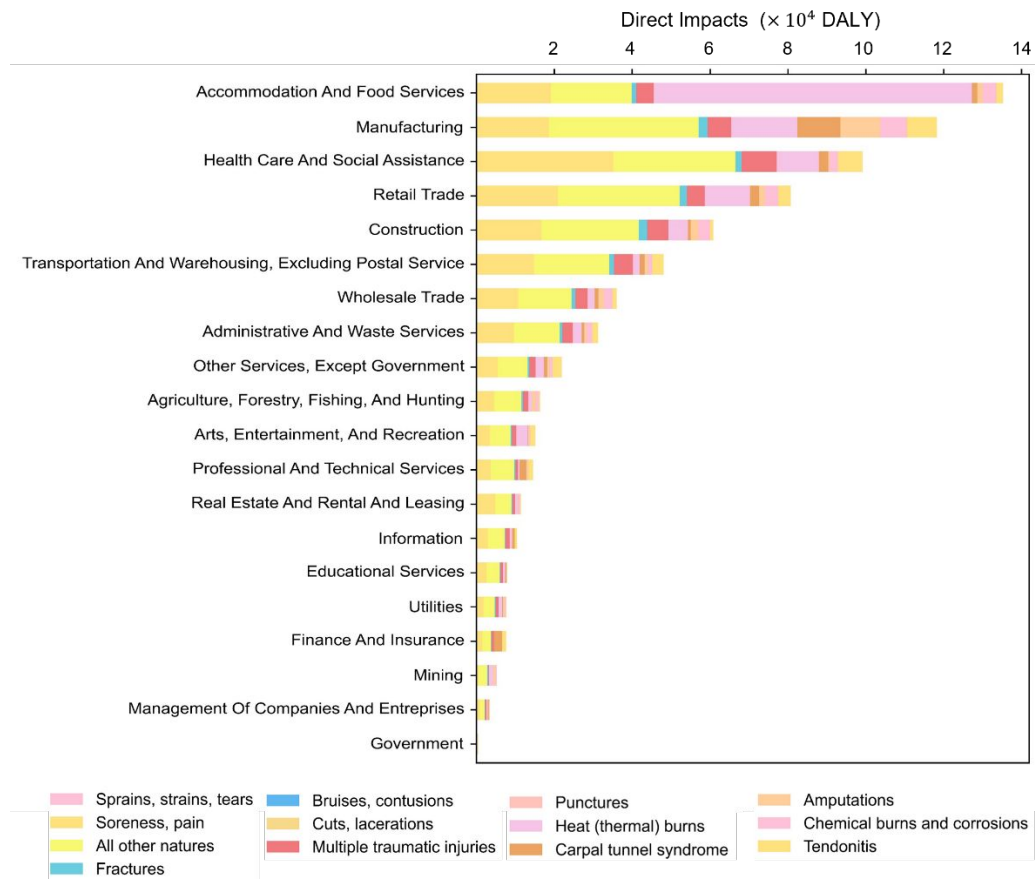
$$c_{SPA} = e_i \mathbf{a}_{ik_1} \mathbf{a}_{k_1 k_2} \dots \mathbf{a}_{k_r j} f_j \quad (\text{Eq. S9})$$

where  $c_{SPA}$  represents the workplace occupational health impact of a supply chain pathway and  $\mathbf{a}_{ik_1}, \mathbf{a}_{k_1 k_2}, \dots$  are the elements of matrix  $\mathbf{A}$ . In this study, we only consider the first two production layers because they already account for 82% of all workplace occupational health impacts in the United States.

### Section S3: Additional notes on results

#### Section S3.1: Direct impacts of occupational health

In order to explain the fact that there is not an exact positive correlation between the number of cases and total occupational health impacts in a specific industry sector, we provide Figure S2 to compare with Figure 1 in the manuscript.

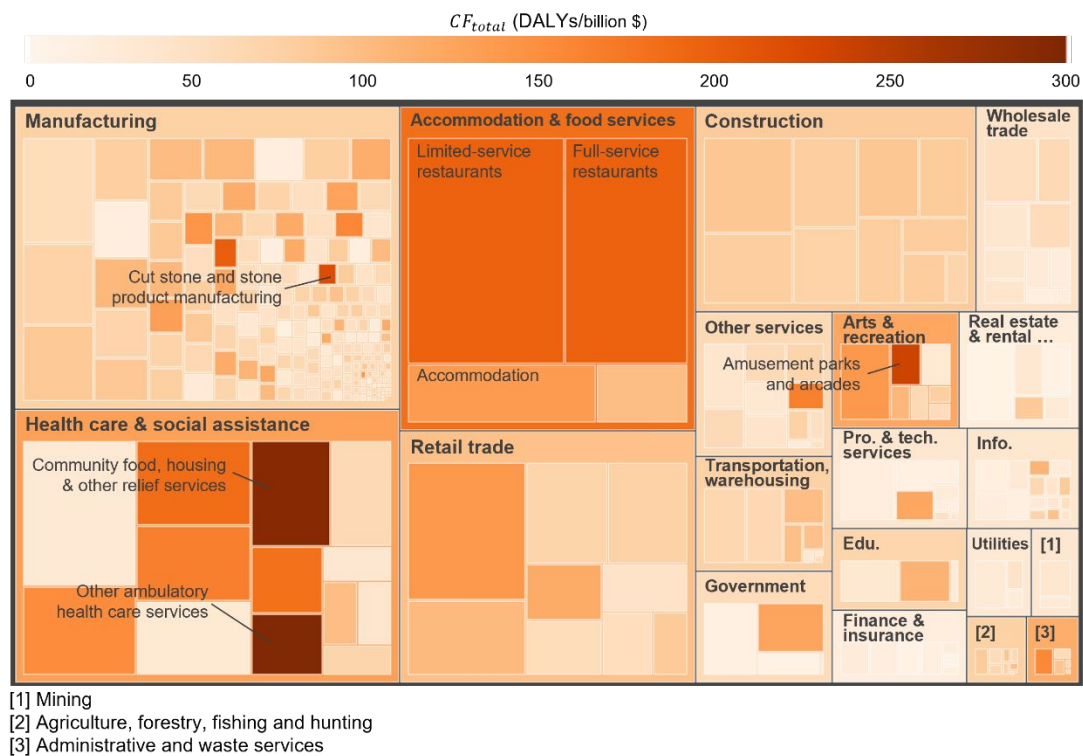


**Figure S2.** Direct impacts of different injuries and illnesses contributed to different industry groups.

When comparing Figure S2 and Figure 1 in the manuscript, we can find that soreness and pain, heat burns and all other natures contribute most in DALY while sprains, strains and tears contribute most in cases. That is because sprains, strains and tears are considered as short-term injuries, which makes them have short duration with low severity. And through Equation 4 in the manuscript, the occupational health impacts of this injury become low in DALY.

### Section S3.2: Total impacts of occupational health (shown in a tree map)

To reduce the occupational health impact of products, more attention should be paid to these sectors. So, in Figure S3, we transform the style of a mosaic plot (Figure 3 in the manuscript) into a tree map (the same style as Figure 2 in the manuscript) to focus on the economic sectors with high occupational health impacts over the entire supply chain.



**Figure S3** Total characterization factors (CF) and total impacts of different industries: the size of the squares represents total impacts of occupational health for the industry; the shade of the color of the squares represents total CF (the darker the color, the greater the  $CF_{total}$ ). To avoid double counting, we use final demand as the denominator to calculate  $CF_{total}$ .

Comparing Figure 2 in the manuscript and Figure S3, “*Manufacturing*” and “*Health care and social assistance*” surpass “*Accommodation and food services*” becoming the first and second economic sectors in terms of occupational health impacts. This indicates that the occupational health impacts of these two economic sectors are mainly influenced by their different supply chains, where the supply chain of “*Manufacturing*” is generally also “*Manufacturing*” itself, while the supply chain of “*Health care and social assistance*” is very complex and diverse. In the contrast, the supply chain of “*Accommodation and food services*” is simple,<sup>12</sup> and the occupational health impacts

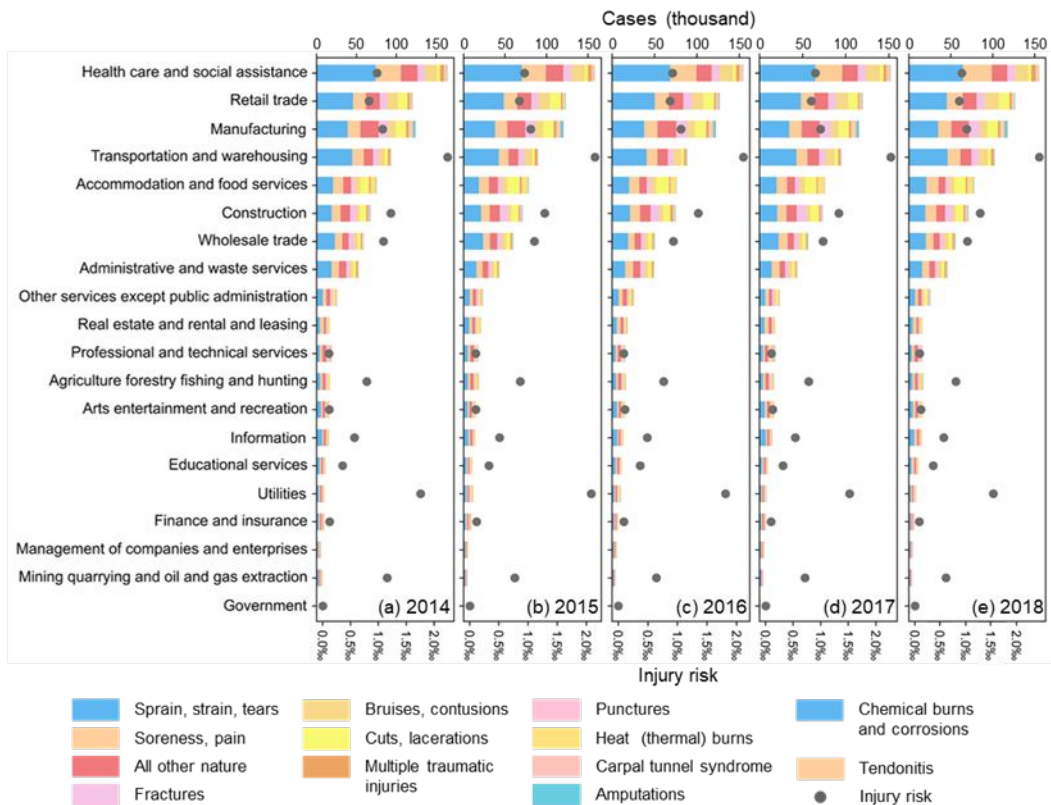
of it come mainly from the industry itself, so the change before and after is relatively small. Besides, Figure 1 in the manuscript uses total output for the calculation, while Figure S1 uses total demand instead. That is because the double counting problem mentioned before only exists after considering the supply chain. That's why the two figures cannot be directly compared.

### **Section S3.3: Result variation between years**

The number and type of nonfatal injuries and illnesses vary from year to year. For example, there were 16% more reported injuries and illnesses in the “*Fruit and tree nut farming*” industry in 2016 than in 2018. To ensure that the derived CFs are representative of typical health outcomes associated with occupational injuries and illnesses (rather than a particularly dangerous or safe year), we collected case data and calculated DALYs for 5-years, and set the CF for each industry based on the 5-year average data.

We used average injury and illness data for five years to evaluate the occupational health impacts by industry in the US. This use of averages represents typical levels of workplace hazards (i.e., central tendency values). An alternate health-protective approach could use the highest values over a period of time, which may be more representative of the potential impact approach commonly used in LCA. Here, we investigate the impact of the use of five-year averages on our derived characterization factors and case study results.

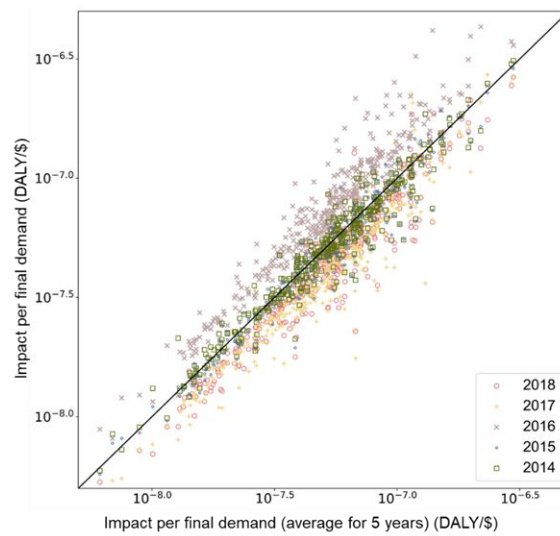
Figure S4 shows the number and mix of nonfatal injury and illness cases reported by year and aggregated into 20 industry groups (for ease of visualization). At this aggregate level, the ranking of sector groups by number of incidents remains the same and the mix of injuries and illnesses within each sector group is similar. However, there is more variation at the industry level (Figures S5 and S6).



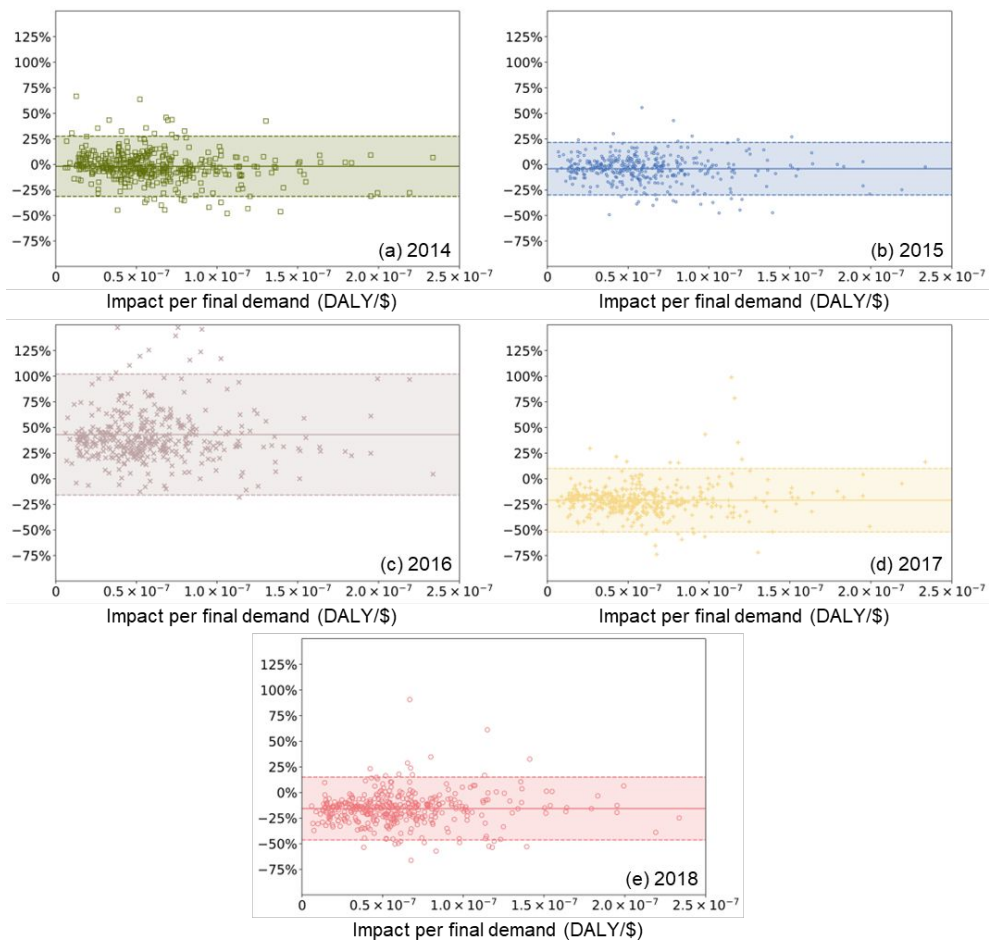
**Figure S4.** Cases of various injuries and risks of different injuries and illnesses in different industry groups for five years. Note that not all industry groups can report this ratio due to missing data on the number of employees in some industry groups (e.g., *real estate and rental and lending*).

We further plotted the figure to compare the difference of characterization factors (CFs) for 397 US industries of these five years with the average ones to investigate the impact of this variation on measured impact. Through Figure S5, we found a strong positive correlation with the line of equality since the line of equality is derived as the average of the other annual values. Figure S6 shows the relative difference between the calculated CFs for a given year with the average calculated CFs. While the CFs for two years (2014, 2015) were more similar to the average CFs, other years were on average more dangerous (mean relative difference of +43% in 2016) or safer (mean relative difference of -21% in 2017 and -15% in 2018). We believe that derived CFs should represent typical levels of workplace hazards (i.e., central tendency values). Therefore, to avoid the potential for selecting a particularly dangerous or safe year and skewing the CFs accordingly, we use 5-year averages to obtain typical CFs. Some LCA researchers and practitioners may argue that a precautionary approach would require the use of health-protective values, or the highest CFs obtained over a period of time.

For researchers and practitioners interested in such an approach, we provided the CFs derived for each industry and year on GitHub.



**Figure S5.** Characterization factors (CFs) for 397 US industries for 5 years compared with the average ones.



**Figure S6.** The relative difference between the calculated CFs for five years with the average calculated CFs

### Section S3.4: Structural path analysis of the U.S. economy

We further identified key supply chain pathways that have an impact on the occupational health of U.S. workers in the work environment (Table S6). The top 20 supply chain pathways all contain only one industry sector and take up more than 35% of total work environment occupational health impacts through the entire economic system. Among them, food service, construction, and transportation had the highest work environment occupational health impacts. This might be due to the large number of workers and low economic output required in these economic sectors, as well as the low education level of workers and a much more hazardous work environment.

**Table S6. The top 20 pathways with the greatest impact on occupational health in the work environment in the U.S. economic system**

Percentage	Direct Impacts	Path
5.71%	3.70E+04	Limited-service restaurants
5.10%	3.31E+04	Full-service restaurants
3.05%	1.98E+04	Food and beverage stores
2.01%	1.30E+04	Individual and family services
1.88%	1.22E+04	Accommodation
1.71%	1.11E+04	Outpatient care centers
1.62%	1.05E+04	Offices of other health practitioners
1.57%	1.02E+04	Motor vehicle and parts dealers
1.56%	1.01E+04	General merchandise stores
1.46%	9.47E+03	Community food, housing, and other relief services, including rehabilitation services
1.19%	7.72E+03	Other residential structures
1.17%	7.58E+03	Other amusement and recreation industries
1.09%	7.09E+03	Offices of physicians
1.06%	6.87E+03	All other food and drinking places
1.06%	6.85E+03	All other retail
0.97%	6.29E+03	Single-family residential structures
0.96%	6.20E+03	Hospitals
0.89%	5.77E+03	Transportation structures and highways and streets
0.88%	5.69E+03	Other ambulatory health care services
0.87%	5.65E+03	Nursing and community care facilities

### Section S3.5: Structural path analysis of the office chair

Through structural path analysis, we can find that the main source of the occupational health impacts of the work environment of office chairs is veneer, plywood and engineered wood product manufacturing. There are 6 paths related to it in the top 10 paths, so whether directly or indirectly, its impact cannot be ignored. This industry includes processes such as wood cutting and wood component manufacturing,



which are highly hazardous. Therefore, if we want to consider reducing the occupational health impact of this product in the work environment, we should improve the technology in this specific industry (Table S7).

**Table S7. 10 paths with the greatest impact on occupational health in the work environment in the production of office chairs**

Percentage	Direct Impact	Path
30.24%	2.98E-06	Veneer, plywood, and engineered wood product manufacturing
11.46%	1.13E-06	Urethane and other foam product (except polystyrene) manufacturing
4.02%	3.96E-07	Sawmills and wood preservation → Veneer, plywood, and engineered wood product manufacturing
3.44%	3.39E-07	Veneer, plywood, and engineered wood product manufacturing → Veneer, plywood, and engineered wood product manufacturing
3.23%	3.18E-07	Paperboard container manufacturing
2.79%	2.75E-07	Plastics material and resin manufacturing
1.64%	1.61E-07	Forestry and logging → Veneer, plywood, and engineered wood product manufacturing
1.50%	1.47E-07	Textile and fabric finishing and fabric coating mills
1.30%	1.27E-07	Other durable goods merchant wholesalers → Veneer, plywood, and engineered wood product manufacturing
0.94%	9.31E-08	Forestry and logging → Support activities for agriculture and forestry → Veneer, plywood, and engineered wood product manufacturing

## Section S4: Uncertainty and sensitivity analysis

### Section S4.1: Uncertainty sources

To ensure that the results of this study are reliable, an uncertainty analysis needs to be performed. Because the data volume is small, the analysis was finally performed by the Monte Carlo method. This was done by assigning the corresponding distributions to all parameters for which there was uncertainty (see Table S8-9 for details) and conducting 1000 sampling for each of the five years of data, and finally fitting the distribution to a mixture of 5000 data samples. The results of the applied distribution fitting were compared with the data from the study by Kijko et al.<sup>13</sup>

**Table S8. Parameters and their distributions**

Variable Name	Symbol	Distribution	Parameters
Severity of short-term injuries and illnesses	$W_{c,ST}$	lognormal	Average, Deviation
Severity of lifelong injuries and illnesses	$W_{c,LL}$	lognormal	Average, Deviation
Duration of short-term injuries and illnesses by different age groups	$D_{c,a,ST}$	uniform	Range (10%) <sup>a</sup>
Duration of lifelong injuries and illnesses by different age groups	$D_{c,a,LL}$	uniform	Range (10%) <sup>a</sup>

a: This range is assumed by authors.

**Table S9. Distribution of severity of different injuries and illnesses**

Type of injuries or illnesses from U.S. Bureau of Labor Statistics	Short-term		Lifelong	
	Average <sup>a</sup>	Deviation <sup>b</sup>	Average <sup>c</sup>	Deviation <sup>b</sup>
Sprains, strains, tears	0.0075	0.68	0	0
Fractures	0.1081	0.85	0.067	0.85
Cuts, lacerations	0.0058	0.68	0.011	0
Puncture wounds	0.0058	0.68	0.011	0
Bruises, contusions	0.0075	0.68	0.008	0
Heat burns	0.2772	0.73	0.180	0.73
Chemical burns	0.2772	0.73	0.180	0.73
Amputations	0.0000	0.68	0.044	0.68
Carpal tunnel syndrome	0.0638	0.68	0.113	0.68
Tendonitis	0.0000	0.68	0.187	0.68
Multiple traumatic injuries	0.1392	0.68	0.058	0.68
Soreness, pain	0.0610	0.68	0.061	0
Unspecified nonfatal injuries	0.0388	0.7025	0.072	0.7186

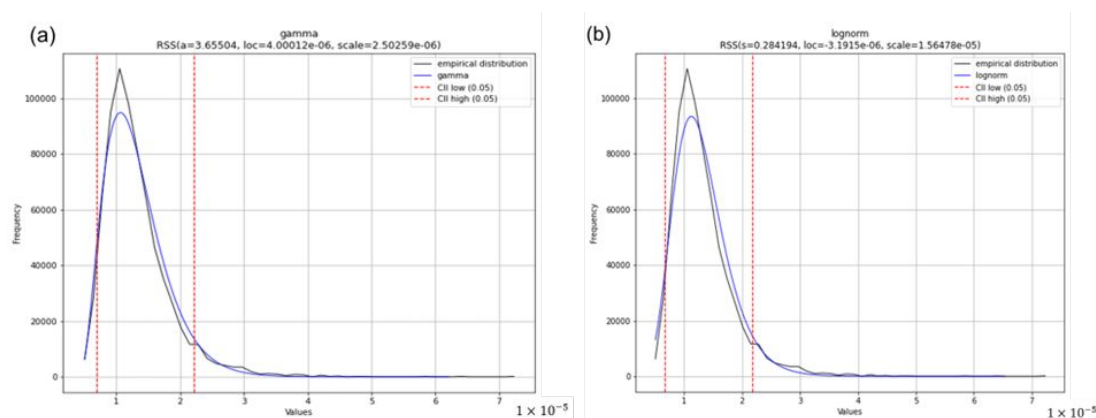
a: This average comes from James et al.<sup>9</sup> work.

b: These deviations are assumed based on Global Burden of Disease report.

c: This average comes from U.S. Bureau of Labor Statistics.

## Section S4.2: Results of the uncertainty analysis

The uncertainty of this study mainly comes from the severity and duration of each injury or illness. The collected data samples mentioned above were calculated separately for the case study, and then the corresponding 5,000 results were obtained. These results were fitted to the distribution according to the density, and the distributions are shown in Figure S4. We found that the best-fitting distribution was the gamma distribution (Figure S7 (a)), while the log-normal distribution (Figure S7 (b)) also had a good fit. Although both distributions have long trailing tails on the right-hand side and low values at the top, the rest of the fitted distributions are too complex without a significant improvement in the fit, so it is finally concluded that the gamma distribution and the lognormal distribution can characterize the uncertainty situation of the framework.



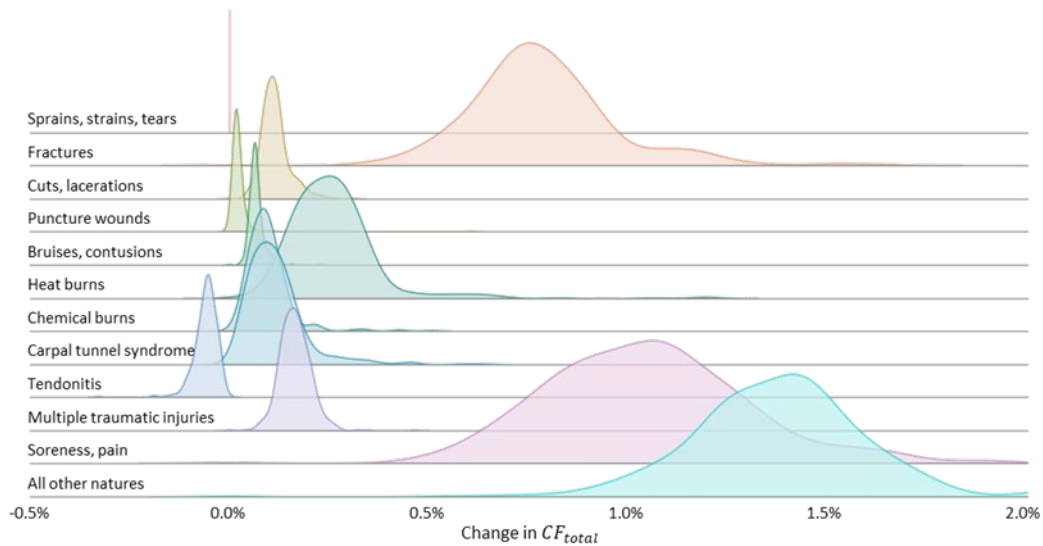
**Figure S7.** Distribution Fitting for 5000 samples; (a) gamma distribution; (b) lognormal distribution; loc here represents mean, and scale represents standard deviation; RSS represents Residual Sum of Squares (a method to compute the goodness of fit test)

## Section S4.3: Sensitivity analysis

We mentioned in the manuscript that the fraction of cases that result in short-term or lifelong health outcomes based on the study of Scanlon et al. and GBD reports is the major assumption in our study. Scanlon et al. (2013) assumed short-term duration for all communicable illnesses, and life-long duration for all non-communicable illnesses, and assigned the fractions of cases that result in short-term or lifelong health outcomes by matching BLS nature codes with GBD sequelae and assigning short-term and life-long fractions accordingly. For injuries, Scanlon et al. (2013) adopted the GBD's assignment of short-term and lifelong duration including for injuries that the GBD assigned as being experienced as short-term for some percentage of the population and

lifelong for the remaining percentage. This “split” occurred for approximately four of the injuries. We adopted the assumptions used in Scanlon et al.’s study with two adjustments as noted in Table S4.

Estimates of the fraction of cases with short-term and life-long health outcomes are highly uncertain. For example, global burden of injury studies estimate the probability of long-term health outcomes based on patient-reported outcome data from three countries (China, Netherlands, and the USA).<sup>14, 15</sup> This resulted in a large range of probabilities of long-term outcomes were some nature-of-injury categories, with some values having to be adjusted because they resulted in an implausibly high burden of disease.<sup>15</sup> For example, the global probability of long-term health loss for a dislocated hip ranged from approximately 20% to just under 100%. To understand the impact of this uncertainty on our results, we conducted a local sensitivity analysis by changing the fraction of lifelong health outcomes for each injury or illness by 10% (except for “Amputation” as we assumed its impact is always lifelong), and compared the results with the baseline. We plotted Figure S8 to justify the sensitivity of industries to different injuries and illnesses.



**Figure S8.** The distribution of the changes in total CFs for the sensitivity analysis. “Amputation” is dropped because it is always lifelong, and “Tendonitis” is declining 1% because it is lifelong due to baseline.

To investigate the sensitivity of industries to different injuries and illnesses, we noted that the changes in total CFs are all lower than 2% due to Figure S8. Among all injuries and illnesses, “Soreness, pain” and “All other nature” contains the largest changes, which justifies that the lifelong split coefficient of these two injuries might affect the total CFs most. It is because the lifelong split coefficient of these two injuries cannot match the GBD report classification directly, and we did the mapping and some assumptions. Further studies can be done due to these results.

**Section S5: New dataset developed in this study**

**Section S5.1: Dataset of direct impact factors of occupational health impacts (Excel version available in [GitHub](#))**

**Table S10. Direct impact factors of occupational health impacts (398 sectors)**

<b>EIO Code</b>	<b>Economic Sectors</b>	<b>Direct impact factors (DALY/\$)</b>
621900	Other ambulatory health care services	2.936E-07
624A00	Community food, housing, and other relief services, including rehabilitation services	2.712E-07
722211	Limited-service restaurants	2.034E-07
327991	Cut stone and stone product manufacturing	1.933E-07
722110	Full-service restaurants	1.797E-07
713100	Amusement parks and arcades	1.732E-07
115000	Support activities for agriculture and forestry	1.678E-07
33712N	Other household nonupholstered furniture	1.671E-07
623B00	Residential mental health, substance abuse, and other residential care facilities	1.626E-07
624100	Individual and family services	1.583E-07
621300	Offices of other health practitioners	1.544E-07
722A00	All other food and drinking places	1.481E-07
812300	Dry-cleaning and laundry services	1.407E-07
561700	Services to buildings and dwellings	1.378E-07
621400	Outpatient care centers	1.335E-07
5191A0	News syndicates, libraries, archives and all other information services	1.221E-07
334610	Manufacturing and reproducing magnetic and optical media	1.114E-07
331520	Nonferrous metal foundries	1.110E-07
112120	Dairy cattle and milk production	1.097E-07
3219A0	All other wood product manufacturing	1.089E-07
221300	Water, sewage and other systems	1.049E-07
611B00	Other educational services	1.042E-07

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445000	Food and beverage stores	1.021E-07
485000	Transit and ground passenger transportation	1.020E-07
541940	Veterinary services	1.014E-07
512200	Sound recording industries	1.014E-07
721000	Accommodation	9.993E-08
811400	Personal and household goods repair and maintenance	9.904E-08
327390	Other concrete product manufacturing	9.865E-08
33721A	Office furniture and custom architectural woodwork and millwork manufacturing	9.794E-08
713900	Other amusement and recreation industries	9.524E-08
532A00	General and consumer goods rental	9.403E-08
337110	Wood kitchen cabinet and countertop manufacturing	9.302E-08
331510	Ferrous metal foundries	9.094E-08
332420	Metal tank (heavy gauge) manufacturing	8.948E-08
712000	Museums, historical sites, zoos, and parks	8.900E-08
493000	Warehousing and storage	8.804E-08
336611	Ship building and repairing	8.552E-08
621500	Medical and diagnostic laboratories	8.539E-08
337127	Institutional furniture manufacturing	8.509E-08
336213	Motor home manufacturing	8.360E-08
337122	Nonupholstered wood household furniture manufacturing	8.207E-08
321100	Sawmills and wood preservation	8.186E-08
314120	Curtain and linen mills	8.040E-08
332800	Coating, engraving, heat treating and allied activities	7.864E-08
334300	Audio and video equipment manufacturing	7.755E-08
561600	Investigation and security services	7.650E-08
811200	Electronic and precision equipment repair and maintenance	7.364E-08
336212	Truck trailer manufacturing	7.325E-08
114000	Fishing, hunting and trapping	7.257E-08
441000	Motor vehicle and parts dealers	7.172E-08

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337900	Other furniture related product manufacturing	7.079E-08
339930	Doll, toy, and game manufacturing	6.919E-08
48A000	Scenic and sightseeing transportation and support activities for transportation	6.902E-08
333514	Special tool, die, jig, and fixture manufacturing	6.880E-08
233230	Manufacturing structures	6.839E-08
311810	Bread and bakery product manufacturing	6.787E-08
327100	Clay product and refractory manufacturing	6.728E-08
332320	Ornamental and architectural metal products manufacturing	6.697E-08
316000	Leather and allied product manufacturing	6.630E-08
444000	Building material and garden equipment and supplies dealers	6.533E-08
311520	Ice cream and frozen dessert manufacturing	6.513E-08
315000	Apparel manufacturing	6.512E-08
332310	Plate work and fabricated structural product manufacturing	6.415E-08
233240	Power and communication structures	6.308E-08
233262	Educational and vocational structures	6.241E-08
335224	Household laundry equipment manufacturing	6.205E-08
483000	Water transportation	6.135E-08
335110	Electric lamp bulb and part manufacturing	6.131E-08
336612	Boat building	6.127E-08
332114	Custom roll forming	6.062E-08
321200	Veneer, plywood, and engineered wood product manufacturing	6.058E-08
314900	Other textile product mills	5.998E-08
336211	Motor vehicle body manufacturing	5.993E-08
332913	Plumbing fixture fitting and trim manufacturing	5.974E-08
311990	All other food manufacturing	5.962E-08
711100	Performing arts companies	5.886E-08
334512	Automatic environmental control manufacturing	5.785E-08
111900	Other crop farming	5.752E-08
2332A0	Office and commercial structures	5.728E-08

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327330	Concrete pipe, brick, and block manufacturing	5.716E-08
2332D0	Other nonresidential structures	5.706E-08
334111	Electronic computer manufacturing	5.690E-08
233411	Single-family residential structures	5.686E-08
336214	Travel trailer and camper manufacturing	5.640E-08
4B0000	All other retail	5.620E-08
447000	Gasoline stations	5.608E-08
230302	Residential maintenance and repair	5.588E-08
2332C0	Transportation structures and highways and streets	5.584E-08
233412	Multifamily residential structures	5.544E-08
233210	Health care structures	5.489E-08
5111A0	Directory, mailing list, and other publishers	5.445E-08
326140	Polystyrene foam product manufacturing	5.396E-08
111300	Fruit and tree nut farming	5.381E-08
2334A0	Other residential structures	5.280E-08
230301	Nonresidential maintenance and repair	5.246E-08
624400	Child day care services	5.187E-08
813A00	Grantmaking, giving, and social advocacy organizations	5.180E-08
812900	Other personal services	5.134E-08
337121	Upholstered household furniture manufacturing	5.088E-08
335228	Other major household appliance manufacturing	5.068E-08
332996	Fabricated pipe and pipe fitting manufacturing	5.011E-08
335912	Primary battery manufacturing	4.963E-08
327320	Ready-mix concrete manufacturing	4.957E-08
339990	All other miscellaneous manufacturing	4.943E-08
486000	Pipeline transportation	4.894E-08
326120	Plastics pipe, pipe fitting, and unlaminated profile shape manufacturing	4.853E-08
561400	Business support services	4.814E-08
333517	Machine tool manufacturing	4.731E-08

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335311	Power, distribution, and specialty transformer manufacturing	4.730E-08
332710	Machine shops	4.667E-08
311615	Poultry processing	4.635E-08
327400	Lime and gypsum product manufacturing	4.558E-08
321910	Millwork	4.478E-08
326130	Laminated plastics plate, sheet (except packaging), and shape manufacturing	4.387E-08
337215	Showcase, partition, shelving, and locker manufacturing	4.373E-08
339114	Dental equipment and supplies manufacturing	4.317E-08
452000	General merchandise stores	4.239E-08
33351B	Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing	4.238E-08
423A00	Other durable goods merchant wholesalers	4.221E-08
334510	Electromedical and electrotherapeutic apparatus manufacturing	4.209E-08
313300	Textile and fabric finishing and fabric coating mills	4.185E-08
446000	Health and personal care stores	4.157E-08
481000	Air transportation	4.065E-08
313200	Fabric mills	4.050E-08
335120	Lighting fixture manufacturing	3.997E-08
623A00	Nursing and community care facilities	3.990E-08
33211A	All other forging, stamping, and sintering	3.989E-08
333994	Industrial process furnace and oven manufacturing	3.989E-08
312120	Breweries	3.969E-08
812200	Death care services	3.896E-08
332999	Other fabricated metal manufacturing	3.886E-08
112A00	Animal production, except cattle and poultry and eggs	3.881E-08
326220	Rubber and plastics hoses and belting manufacturing	3.864E-08
312110	Soft drink and ice manufacturing	3.850E-08
484000	Truck transportation	3.772E-08
332600	Spring and wire product manufacturing	3.715E-08
333511	Industrial mold manufacturing	3.665E-08

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311420	Fruit and vegetable canning, pickling, and drying	3.626E-08
561500	Travel arrangement and reservation services	3.596E-08
424400	Grocery and related product wholesalers	3.483E-08
448000	Clothing and clothing accessories stores	3.388E-08
327993	Mineral wool manufacturing	3.379E-08
335222	Household refrigerator and home freezer manufacturing	3.345E-08
335210	Small electrical appliance manufacturing	3.320E-08
333316	Photographic and photocopying equipment manufacturing	3.309E-08
327992	Ground or treated mineral and earth manufacturing	3.304E-08
111400	Greenhouse, nursery, and floriculture production	3.303E-08
311410	Frozen food manufacturing	3.290E-08
339920	Sporting and athletic goods manufacturing	3.284E-08
541920	Photographic services	3.259E-08
33329A	Other industrial machinery manufacturing	3.256E-08
322230	Stationery product manufacturing	3.231E-08
424A00	Other nondurable goods merchant wholesalers	3.227E-08
327910	Abrasive product manufacturing	3.225E-08
331200	Steel product manufacturing from purchased steel	3.216E-08
33641A	Propulsion units and parts for space vehicles and guided missiles	3.204E-08
621600	Home health care services	3.184E-08
335911	Storage battery manufacturing	3.175E-08
811100	Automotive repair and maintenance	3.167E-08
323120	Support activities for printing	3.061E-08
339940	Office supplies (except paper) manufacturing	3.056E-08
339950	Sign manufacturing	3.020E-08
333920	Material handling equipment manufacturing	3.007E-08
33399B	Fluid power process machinery	2.994E-08
335991	Carbon and graphite product manufacturing	2.989E-08
33441A	Other electronic component manufacturing	2.961E-08

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813B00	Civic, social, professional, and similar organizations	2.958E-08
3118A0	Cookie, cracker, pasta, and tortilla manufacturing	2.955E-08
511110	Newspaper publishers	2.945E-08
323110	Printing	2.931E-08
31161A	Animal (except poultry) slaughtering, rendering, and processing	2.917E-08
113000	Forestry and logging	2.911E-08
33299A	Ammunition, arms, ordnance, and accessories manufacturing	2.894E-08
327200	Glass and glass product manufacturing	2.888E-08
322299	All other converted paper product manufacturing	2.881E-08
327999	Miscellaneous nonmetallic mineral products	2.870E-08
326210	Tire manufacturing	2.859E-08
541400	Specialized design services	2.842E-08
812100	Personal care services	2.809E-08
311300	Sugar and confectionery product manufacturing	2.779E-08
5416A0	Environmental and other technical consulting services	2.777E-08
336111	Automobile manufacturing	2.765E-08
332200	Cutlery and handtool manufacturing	2.726E-08
31151A	Fluid milk and butter manufacturing	2.684E-08
711200	Spectator sports	2.681E-08
711A00	Promoters of performing arts and sports and agents for public figures	2.664E-08
333314	Optical instrument and lens manufacturing	2.653E-08
326290	Other rubber product manufacturing	2.629E-08
325910	Printing ink manufacturing	2.609E-08
21311A	Other support activities for mining	2.604E-08
212310	Stone mining and quarrying	2.567E-08
532400	Commercial and industrial machinery and equipment rental and leasing	2.549E-08
2123A0	Other nonmetallic mineral mining and quarrying	2.541E-08
454000	Nonstore retailers	2.529E-08
333613	Mechanical power transmission equipment manufacturing	2.524E-08

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336360	Motor vehicle seating and interior trim manufacturing	2.516E-08
335313	Switchgear and switchboard apparatus manufacturing	2.479E-08
311513	Cheese manufacturing	2.457E-08
326150	Urethane and other foam product (except polystyrene) manufacturing	2.436E-08
326110	Plastics packaging materials and unlaminated film and sheet manufacturing	2.432E-08
332119	Metal crown, closure, and other metal stamping (except automotive)	2.425E-08
326190	Other plastics product manufacturing	2.417E-08
561900	Other support services	2.409E-08
336390	Other Motor Vehicle Parts Manufacturing	2.407E-08
311940	Seasoning and dressing manufacturing	2.382E-08
3363A0	Motor vehicle steering, suspension component (except spring), and brake systems manufacturing	2.369E-08
333414	Heating equipment (except warm air furnaces) manufacturing	2.361E-08
333612	Speed changer, industrial high-speed drive, and gear manufacturing	2.341E-08
517A00	Satellite, telecommunications resellers, and all other telecommunications	2.340E-08
532100	Automotive equipment rental and leasing	2.321E-08
339910	Jewelry and silverware manufacturing	2.288E-08
336370	Motor vehicle metal stamping	2.284E-08
335930	Wiring device manufacturing	2.278E-08
339115	Ophthalmic goods manufacturing	2.269E-08
311210	Flour milling and malt manufacturing	2.242E-08
322220	Paper Bag and Coated and Treated Paper Manufacturing	2.237E-08
814000	Private households	2.218E-08
331313	Alumina refining and primary aluminum production	2.139E-08
333111	Farm machinery and equipment manufacturing	2.137E-08
332410	Power boiler and heat exchanger manufacturing	2.127E-08
333112	Lawn and garden equipment manufacturing	2.122E-08
325120	Industrial gas manufacturing	2.117E-08
339116	Dental laboratories	2.097E-08
111200	Vegetable and melon farming	2.088E-08

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331490	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying	2.079E-08
621200	Offices of dentists	2.078E-08
333991	Power-driven handtool manufacturing	2.053E-08
112300	Poultry and egg production	2.043E-08
713200	Gambling industries (except casino hotels)	2.024E-08
33291A	Valve and fittings other than plumbing	2.016E-08
334290	Other communications equipment manufacturing	2.014E-08
335221	Household cooking appliance manufacturing	1.997E-08
311910	Snack food manufacturing	1.959E-08
324122	Asphalt shingle and coating materials manufacturing	1.906E-08
332720	Turned product and screw, nut, and bolt manufacturing	1.901E-08
423100	Motor vehicle and motor vehicle parts and supplies	1.886E-08
325510	Paint and coating manufacturing	1.863E-08
3259A0	All other chemical product and preparation manufacturing	1.862E-08
333413	Industrial and commercial fan and blower and air purification equipment manufacturing	1.854E-08
332991	Ball and roller bearing manufacturing	1.851E-08
336999	All other transportation equipment manufacturing	1.837E-08
331420	Copper rolling, drawing, extruding and alloying	1.833E-08
312130	Wineries	1.822E-08
336320	Motor vehicle electrical and electronic equipment manufacturing	1.816E-08
325130	Synthetic dye and pigment manufacturing	1.810E-08
423800	Machinery, equipment, and supplies	1.795E-08
33399A	Other general purpose machinery manufacturing	1.775E-08
327310	Cement manufacturing	1.761E-08
423400	Professional and commercial equipment and supplies	1.750E-08
322210	Paperboard container manufacturing	1.741E-08
333993	Packaging machinery manufacturing	1.738E-08
336991	Motorcycle, bicycle, and parts manufacturing	1.730E-08
336350	Motor vehicle transmission and power train parts manufacturing	1.694E-08

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332500	Hardware manufacturing	1.673E-08
325610	Soap and cleaning compound manufacturing	1.669E-08
331410	Nonferrous Metal (except Aluminum) Smelting and Refining	1.641E-08
333318	Other commercial and service industry machinery manufacturing	1.636E-08
621100	Offices of physicians	1.609E-08
333120	Construction machinery manufacturing	1.605E-08
313100	Fiber, yarn, and thread mills	1.580E-08
325520	Adhesive manufacturing	1.574E-08
33391A	Pump and pumping equipment manufacturing	1.569E-08
221100	Electric power generation, transmission, and distribution	1.529E-08
512100	Motion picture and video industries	1.522E-08
311920	Coffee and tea manufacturing	1.484E-08
336413	Other aircraft parts and auxiliary equipment manufacturing	1.462E-08
515100	Radio and television broadcasting	1.442E-08
335312	Motor and generator manufacturing	1.432E-08
322110	Pulp mills	1.421E-08
336310	Motor vehicle gasoline engine and engine parts manufacturing	1.420E-08
333912	Air and gas compressor manufacturing	1.415E-08
314110	Carpet and rug mills	1.411E-08
332430	Metal can, box, and other metal container (light gauge) manufacturing	1.404E-08
333130	Mining and oil and gas field machinery manufacturing	1.403E-08
336992	Military armored vehicle, tank, and tank component manufacturing	1.400E-08
335999	All other miscellaneous electrical equipment and component manufacturing	1.399E-08
212100	Coal mining	1.378E-08
335314	Relay and industrial control manufacturing	1.374E-08
33451A	Watch, clock, and other measuring and controlling device manufacturing	1.365E-08
425000	Wholesale electronic markets and agents and brokers	1.360E-08
325310	Fertilizer manufacturing	1.357E-08
336500	Railroad rolling stock manufacturing	1.344E-08

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541800	Advertising, public relations, and related services	1.335E-08
326160	Plastics bottle manufacturing	1.333E-08
325411	Medicinal and botanical manufacturing	1.333E-08
213111	Drilling oil and gas wells	1.312E-08
322291	Sanitary paper product manufacturing	1.288E-08
325180	Other Basic Inorganic Chemical Manufacturing	1.282E-08
325620	Toilet preparation manufacturing	1.248E-08
311111	Dog and cat food manufacturing	1.243E-08
339112	Surgical and medical instrument manufacturing	1.238E-08
333415	Air conditioning, refrigeration, and warm air heating equipment manufacturing	1.232E-08
339113	Surgical appliance and supplies manufacturing	1.193E-08
33131B	Aluminum product manufacturing from purchased aluminum	1.187E-08
3252A0	Synthetic rubber and artificial and synthetic fibers and filaments manufacturing	1.186E-08
334513	Industrial process variable instruments manufacturing	1.185E-08
334514	Totalizing fluid meter and counting device manufacturing	1.184E-08
561200	Facilities support services	1.183E-08
611100	Elementary and secondary schools	1.163E-08
335920	Communication and energy wire and cable manufacturing	1.149E-08
311119	Other animal food manufacturing	1.143E-08
311700	Seafood product preparation and packaging	1.138E-08
482000	Rail transportation	1.128E-08
811300	Commercial and industrial machinery and equipment repair and maintenance	1.119E-08
511120	Periodical Publishers	1.062E-08
334515	Electricity and signal testing instruments manufacturing	1.050E-08
325413	In-vitro diagnostic substance manufacturing	1.038E-08
423600	Household appliances and electrical and electronic goods	1.034E-08
334112	Computer storage device manufacturing	1.032E-08
1111B0	Grain farming	1.001E-08
311230	Breakfast cereal manufacturing	9.887E-09

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325320	Pesticide and other agricultural chemical manufacturing	9.689E-09
492000	Couriers and messengers	9.638E-09
2122A0	Iron, gold, silver, and other metal ore mining	9.623E-09
311930	Flavoring syrup and concentrate manufacturing	9.599E-09
622000	Hospitals	9.446E-09
324190	Other petroleum and coal products manufacturing	9.142E-09
511130	Book publishers	9.126E-09
334517	Irradiation apparatus manufacturing	9.066E-09
334118	Computer terminals and other computer peripheral equipment manufacturing	8.710E-09
221200	Natural gas distribution	8.701E-09
711500	Independent artists, writers, and performers	8.694E-09
541300	Architectural, engineering, and related services	8.637E-09
334516	Analytical laboratory instrument manufacturing	8.451E-09
336411	Aircraft manufacturing	8.338E-09
325414	Biological product (except diagnostic) manufacturing	8.245E-09
334418	Printed circuit assembly (electronic assembly) manufacturing	8.161E-09
333611	Turbine and turbine generator set units manufacturing	7.823E-09
312140	Distilleries	7.786E-09
5419A0	All other miscellaneous professional, scientific, and technical services	7.771E-09
1111A0	Oilseed farming	7.223E-09
322120	Paper mills	7.209E-09
525000	Funds, trusts, and other financial vehicles	7.203E-09
550000	Management of companies and enterprises	7.135E-09
54151A	Other computer related services, including facilities management	6.808E-09
561300	Employment services	6.741E-09
333242	Semiconductor machinery manufacturing	6.559E-09
311224	Soybean and other oilseed processing	6.380E-09
424700	Petroleum and petroleum products	6.372E-09
311225	Fats and oils refining and blending	6.364E-09

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334210	Telephone apparatus manufacturing	6.298E-09
325412	Pharmaceutical preparation manufacturing	6.271E-09
336120	Heavy duty truck manufacturing	6.240E-09
324121	Asphalt paving mixture and block manufacturing	6.237E-09
325211	Plastics material and resin manufacturing	6.084E-09
311221	Wet corn milling	6.006E-09
1121A0	Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming	5.894E-09
541200	Accounting, tax preparation, bookkeeping, and payroll services	5.837E-09
561100	Office administrative services	5.819E-09
491000	Postal service	5.690E-09
322130	Paperboard mills	5.669E-09
336112	Light truck and utility vehicle manufacturing	5.596E-09
333618	Other engine equipment manufacturing	5.425E-09
212230	Copper, nickel, lead, and zinc mining	5.287E-09
311514	Dry, condensed, and evaporated dairy product manufacturing	5.152E-09
522A00	Nondepository credit intermediation and related activities	5.114E-09
336412	Aircraft engine and engine parts manufacturing	4.808E-09
541610	Management consulting services	4.760E-09
813100	Religious organizations	4.731E-09
334413	Semiconductor and related device manufacturing	4.698E-09
531HST	Tenant-occupied housing	4.402E-09
531ORE	Other real estate	4.279E-09
541511	Custom computer programming services	4.213E-09
524200	Insurance agencies, brokerages, and related activities	4.159E-09
52A000	Monetary authorities and depository credit intermediation	3.934E-09
611A00	Junior colleges, colleges, universities, and professional schools	3.892E-09
336414	Guided missile and space vehicle manufacturing	3.830E-09
424200	Drugs and druggists' sundries	3.817E-09
519130	Internet publishing and broadcasting and Web search portals	3.783E-09

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334220	Broadcast and wireless communications equipment	3.610E-09
523A00	Securities and commodity contracts intermediation and brokerage	3.575E-09
515200	Cable and other subscription programming	3.554E-09
334511	Search, detection, and navigation instruments manufacturing	3.552E-09
325190	Other basic organic chemical manufacturing	3.466E-09
541700	Scientific research and development services	3.091E-09
541512	Computer systems design services	2.723E-09
523900	Other financial investment activities	2.611E-09
541100	Legal services	2.455E-09
518200	Data processing, hosting, and related services	2.437E-09
533000	Lessors of nonfinancial intangible assets	2.363E-09
312200	Tobacco product manufacturing	2.160E-09
524113	Direct life insurance carriers	1.714E-09
5241XX	Insurance carriers, except direct life	1.638E-09
511200	Software publishers	1.621E-09
517210	Wireless telecommunications carriers (except satellite)	1.287E-09
325110	Petrochemical manufacturing	1.276E-09
211000	Oil and gas extraction	1.271E-09
331110	Iron and steel mills and ferroalloy manufacturing	1.080E-09
517110	Wired telecommunications carriers	9.549E-10
324110	Petroleum refineries	3.651E-10
4200ID	Customs duties	0
531HSO	Owner-occupied housing	0
S00500	Federal general government (defense)	0
S00600	Federal general government (nondefense)	0
S00102	Other federal government enterprises	0
S00203	Other state and local government enterprises	0

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\*Details about uncertainty (confidence interval) can be found on GitHub (<https://github.com/ZhehanHuang/Occupational-health-calculation/tree/main/uncertainty>)

**Section S5.2: Dataset of total characterization factors ( $CF_{total}$ ) for occupational health impacts**

**Table S11. Total characterization factors ( $CF_{total}$ ) for occupational health impacts (398 sectors) (Excel version available in [GitHub](#))**

<b>EIO Code</b>	<b>Economic Sectors</b>	<b><math>CF_{total}</math> (DALYs/\$)</b>	<b><math>CF_{SD}</math> (DALYs/\$)</b>	<b><math>CF_{Sc}</math> (DALYs/\$)</b>
621900	Other ambulatory health care services	2.980E-07	2.831E-07	1.490E-08
624A00	Community food, housing, and other relief services, including rehabilitation services	2.925E-07	2.597E-07	3.281E-08
713100	Amusement parks and arcades	2.337E-07	2.169E-07	1.676E-08
327991	Cut stone and stone product manufacturing	2.192E-07	1.862E-07	3.296E-08
33712N	Other household nonupholstered furniture	1.994E-07	1.641E-07	3.530E-08
722110	Full-service restaurants	1.953E-07	1.768E-07	1.850E-08
722211	Limited-service restaurants	1.952E-07	1.710E-07	2.418E-08
624100	Individual and family services	1.833E-07	1.640E-07	1.936E-08
623B00	Residential mental health, substance abuse, and other residential care facilities	1.794E-07	1.622E-07	1.722E-08
621300	Offices of other health practitioners	1.641E-07	1.543E-07	9.813E-09
812300	Dry-cleaning and laundry services	1.635E-07	1.414E-07	2.211E-08
3219A0	All other wood product manufacturing	1.550E-07	1.081E-07	4.690E-08
561700	Services to buildings and dwellings	1.539E-07	1.368E-07	1.709E-08
112120	Dairy cattle and milk production	1.515E-07	1.119E-07	3.958E-08
115000	Support activities for agriculture and forestry	1.512E-07	1.360E-07	1.517E-08
621400	Outpatient care centers	1.504E-07	1.295E-07	2.086E-08
331520	Nonferrous metal foundries	1.411E-07	1.111E-07	3.009E-08
33721A	Office furniture and custom architectural woodwork and millwork manufacturing	1.393E-07	9.829E-08	4.103E-08
713900	Other amusement and recreation industries	1.363E-07	1.157E-07	2.067E-08
445000	Food and beverage stores	1.361E-07	1.178E-07	1.825E-08
337110	Wood kitchen cabinet and countertop manufacturing	1.356E-07	9.493E-08	4.068E-08
721000	Accommodation	1.338E-07	1.175E-07	1.635E-08

327390	Other concrete product manufacturing	1.303E-07	9.926E-08	3.105E-08
311513	Cheese manufacturing	1.288E-07	2.616E-08	1.027E-07
321100	Sawmills and wood preservation	1.254E-07	7.313E-08	5.231E-08
337122	Nonupholstered wood household furniture manufacturing	1.248E-07	8.172E-08	4.312E-08
S00203	Other state and local government enterprises	1.231E-07	9.456E-08	2.856E-08
541940	Veterinary services	1.204E-07	1.088E-07	1.165E-08
337127	Institutional furniture manufacturing	1.191E-07	8.397E-08	3.516E-08
332420	Metal tank (heavy gauge) manufacturing	1.180E-07	8.929E-08	2.870E-08
337900	Other furniture related product manufacturing	1.158E-07	7.074E-08	4.510E-08
447000	Gasoline stations	1.153E-07	9.302E-08	2.227E-08
336212	Truck trailer manufacturing	1.153E-07	7.322E-08	4.204E-08
311520	Ice cream and frozen dessert manufacturing	1.150E-07	5.726E-08	5.770E-08
336213	Motor home manufacturing	1.143E-07	7.717E-08	3.710E-08
321910	Millwork	1.140E-07	6.080E-08	5.323E-08
314120	Curtain and linen mills	1.139E-07	7.550E-08	3.837E-08
336611	Ship building and repairing	1.136E-07	8.865E-08	2.491E-08
493000	Warehousing and storage	1.132E-07	8.464E-08	2.858E-08
321200	Veneer, plywood, and engineered wood product manufacturing	1.124E-07	6.213E-08	5.030E-08
31151A	Fluid milk and butter manufacturing	1.121E-07	2.703E-08	8.508E-08
331510	Ferrous metal foundries	1.114E-07	9.053E-08	2.092E-08
611B00	Other educational services	1.073E-07	9.001E-08	1.727E-08
336214	Travel trailer and camper manufacturing	1.063E-07	5.921E-08	4.705E-08
336211	Motor vehicle body manufacturing	1.055E-07	6.434E-08	4.117E-08
512200	Sound recording industries	1.044E-07	9.374E-08	1.068E-08
337121	Upholstered household furniture manufacturing	1.024E-07	5.767E-08	4.477E-08
332800	Coating, engraving, heat treating and allied activities	1.024E-07	7.738E-08	2.504E-08
712000	Museums, historical sites, zoos, and parks	1.024E-07	8.672E-08	1.565E-08
311615	Poultry processing	1.017E-07	4.594E-08	5.580E-08
316000	Leather and allied product manufacturing	1.016E-07	6.608E-08	3.548E-08

311990	All other food manufacturing	1.004E-07	5.307E-08	4.733E-08
336612	Boat building	9.945E-08	6.457E-08	3.488E-08
441000	Motor vehicle and parts dealers	9.942E-08	8.614E-08	1.327E-08
332310	Plate work and fabricated structural product manufacturing	9.905E-08	6.775E-08	3.130E-08
332913	Plumbing fixture fitting and trim manufacturing	9.770E-08	6.241E-08	3.529E-08
311514	Dry, condensed, and evaporated dairy product manufacturing	9.765E-08	1.999E-08	7.765E-08
334300	Audio and video equipment manufacturing	9.748E-08	7.429E-08	2.319E-08
485000	Transit and ground passenger transportation	9.552E-08	7.877E-08	1.674E-08
621500	Medical and diagnostic laboratories	9.550E-08	8.542E-08	1.009E-08
722A00	All other food and drinking places	9.499E-08	8.011E-08	1.489E-08
327330	Concrete pipe, brick, and block manufacturing	9.449E-08	6.080E-08	3.369E-08
332320	Ornamental and architectural metal products manufacturing	9.446E-08	6.679E-08	2.767E-08
327100	Clay product and refractory manufacturing	9.289E-08	6.582E-08	2.707E-08
483000	Water transportation	9.270E-08	6.275E-08	2.994E-08
111900	Other crop farming	9.221E-08	6.127E-08	3.094E-08
5191A0	News syndicates, libraries, archives and all other information services	9.084E-08	8.053E-08	1.031E-08
335224	Household laundry equipment manufacturing	9.063E-08	6.130E-08	2.933E-08
48A000	Scenic and sightseeing transportation and support activities for transportation	9.052E-08	6.075E-08	2.977E-08
334610	Manufacturing and reproducing magnetic and optical media	8.990E-08	7.700E-08	1.290E-08
332114	Custom roll forming	8.958E-08	6.122E-08	2.836E-08
230302	Residential maintenance and repair	8.721E-08	5.201E-08	3.520E-08
561600	Investigation and security services	8.688E-08	7.319E-08	1.368E-08
114000	Fishing, hunting and trapping	8.529E-08	7.108E-08	1.421E-08
2332D0	Other nonresidential structures	8.521E-08	5.221E-08	3.300E-08
2334A0	Other residential structures	8.499E-08	5.203E-08	3.296E-08
230301	Nonresidential maintenance and repair	8.492E-08	5.196E-08	3.296E-08
311810	Bread and bakery product manufacturing	8.360E-08	5.205E-08	3.155E-08
327320	Ready-mix concrete manufacturing	8.341E-08	5.181E-08	3.160E-08
339930	Doll, toy, and game manufacturing	8.317E-08	6.137E-08	2.180E-08

311410	Frozen food manufacturing	8.310E-08	3.288E-08	5.022E-08
314900	Other textile product mills	8.280E-08	4.980E-08	3.300E-08
315000	Apparel manufacturing	8.273E-08	5.939E-08	2.334E-08
332600	Spring and wire product manufacturing	8.241E-08	5.110E-08	3.130E-08
313200	Fabric mills	8.227E-08	5.156E-08	3.070E-08
326140	Polystyrene foam product manufacturing	8.122E-08	5.234E-08	2.887E-08
111300	Fruit and tree nut farming	8.104E-08	5.547E-08	2.557E-08
335110	Electric lamp bulb and part manufacturing	8.084E-08	5.731E-08	2.353E-08
444000	Building material and garden equipment and supplies dealers	8.075E-08	6.865E-08	1.209E-08
311420	Fruit and vegetable canning, pickling, and drying	8.043E-08	3.109E-08	4.933E-08
532A00	General and consumer goods rental	8.034E-08	6.564E-08	1.471E-08
511110	Newspaper publishers	7.992E-08	6.518E-08	1.474E-08
333514	Special tool, die, jig, and fixture manufacturing	7.990E-08	5.748E-08	2.242E-08
337215	Showcase, partition, shelving, and locker manufacturing	7.966E-08	4.648E-08	3.318E-08
2332A0	Office and commercial structures	7.952E-08	5.220E-08	2.732E-08
233230	Manufacturing structures	7.830E-08	5.220E-08	2.610E-08
233210	Health care structures	7.811E-08	5.220E-08	2.591E-08
332996	Fabricated pipe and pipe fitting manufacturing	7.809E-08	5.003E-08	2.805E-08
333517	Machine tool manufacturing	7.795E-08	4.869E-08	2.925E-08
2332C0	Transportation structures and highways and streets	7.736E-08	5.220E-08	2.515E-08
233262	Educational and vocational structures	7.735E-08	5.220E-08	2.515E-08
233411	Single-family residential structures	7.734E-08	5.220E-08	2.514E-08
336360	Motor vehicle seating and interior trim manufacturing	7.627E-08	2.532E-08	5.095E-08
339990	All other miscellaneous manufacturing	7.603E-08	4.984E-08	2.619E-08
31161A	Animal (except poultry) slaughtering, rendering, and processing	7.599E-08	2.936E-08	4.663E-08
335912	Primary battery manufacturing	7.586E-08	4.975E-08	2.612E-08
312110	Soft drink and ice manufacturing	7.478E-08	3.830E-08	3.648E-08
3118A0	Cookie, cracker, pasta, and tortilla manufacturing	7.468E-08	3.312E-08	4.156E-08
711A00	Promoters of performing arts and sports and agents for public figures	7.441E-08	5.679E-08	1.762E-08

335228	Other major household appliance manufacturing	7.437E-08	5.082E-08	2.354E-08
326120	Plastics pipe, pipe fitting, and unlaminated profile shape manufacturing	7.214E-08	4.746E-08	2.467E-08
335311	Power, distribution, and specialty transformer manufacturing	7.210E-08	4.626E-08	2.585E-08
332710	Machine shops	7.203E-08	4.583E-08	2.620E-08
327400	Lime and gypsum product manufacturing	7.157E-08	4.620E-08	2.537E-08
112300	Poultry and egg production	7.126E-08	2.245E-08	4.881E-08
313300	Textile and fabric finishing and fabric coating mills	7.121E-08	3.377E-08	3.744E-08
4B0000	All other retail	7.120E-08	5.605E-08	1.515E-08
811400	Personal and household goods repair and maintenance	7.117E-08	5.942E-08	1.175E-08
336111	Automobile manufacturing	7.069E-08	2.726E-08	4.343E-08
339950	Sign manufacturing	7.057E-08	4.081E-08	2.976E-08
3363A0	Motor vehicle steering, suspension component (except spring), and brake systems manufacturing	7.044E-08	2.393E-08	4.650E-08
233240	Power and communication structures	7.043E-08	5.220E-08	1.823E-08
33211A	All other forging, stamping, and sintering	7.018E-08	3.731E-08	3.286E-08
311920	Coffee and tea manufacturing	6.973E-08	1.634E-08	5.338E-08
326220	Rubber and plastics hoses and belting manufacturing	6.958E-08	3.708E-08	3.250E-08
311940	Seasoning and dressing manufacturing	6.875E-08	2.428E-08	4.447E-08
311300	Sugar and confectionery product manufacturing	6.871E-08	2.689E-08	4.182E-08
33351B	Cutting and machine tool accessory, rolling mill, and other metalworking machinery manufacturing	6.850E-08	4.271E-08	2.579E-08
312120	Breweries	6.845E-08	3.964E-08	2.881E-08
336350	Motor vehicle transmission and power train parts manufacturing	6.827E-08	1.658E-08	5.169E-08
336310	Motor vehicle gasoline engine and engine parts manufacturing	6.779E-08	1.566E-08	5.213E-08
326130	Laminated plastics plate, sheet (except packaging), and shape manufacturing	6.778E-08	4.091E-08	2.687E-08
334111	Electronic computer manufacturing	6.766E-08	6.113E-08	6.527E-09
336390	Other Motor Vehicle Parts Manufacturing	6.766E-08	2.521E-08	4.245E-08
333994	Industrial process furnace and oven manufacturing	6.741E-08	4.041E-08	2.700E-08
311700	Seafood product preparation and packaging	6.738E-08	1.242E-08	5.496E-08
331490	Nonferrous metal (except copper and aluminum) rolling, drawing, extruding and alloying	6.721E-08	3.385E-08	3.336E-08
452000	General merchandise stores	6.712E-08	5.030E-08	1.683E-08



334512	Automatic environmental control manufacturing	6.688E-08	5.119E-08	1.569E-08
624400	Child day care services	6.680E-08	4.887E-08	1.793E-08
326210	Tire manufacturing	6.679E-08	2.977E-08	3.702E-08
339920	Sporting and athletic goods manufacturing	6.677E-08	3.404E-08	3.273E-08
335120	Lighting fixture manufacturing	6.673E-08	3.890E-08	2.782E-08
813A00	Grantmaking, giving, and social advocacy organizations	6.665E-08	5.258E-08	1.407E-08
5111A0	Directory, mailing list, and other publishers	6.624E-08	4.846E-08	1.778E-08
311210	Flour milling and malt manufacturing	6.623E-08	2.330E-08	4.293E-08
113000	Forestry and logging	6.603E-08	2.722E-08	3.881E-08
233412	Multifamily residential structures	6.599E-08	5.221E-08	1.378E-08
332999	Other fabricated metal manufacturing	6.547E-08	3.905E-08	2.642E-08
333112	Lawn and garden equipment manufacturing	6.496E-08	2.210E-08	4.286E-08
327992	Ground or treated mineral and earth manufacturing	6.471E-08	3.989E-08	2.482E-08
481000	Air transportation	6.391E-08	4.141E-08	2.250E-08
33329A	Other industrial machinery manufacturing	6.377E-08	3.348E-08	3.029E-08
S00102	Other federal government enterprises	6.280E-08	3.530E-08	2.750E-08
111400	Greenhouse, nursery, and floriculture production	6.262E-08	3.492E-08	2.770E-08
326290	Other rubber product manufacturing	6.207E-08	2.855E-08	3.351E-08
322230	Stationery product manufacturing	6.193E-08	3.012E-08	3.181E-08
561400	Business support services	6.132E-08	4.446E-08	1.686E-08
333920	Material handling equipment manufacturing	6.125E-08	3.044E-08	3.081E-08
339114	Dental equipment and supplies manufacturing	6.114E-08	4.278E-08	1.836E-08
313100	Fiber, yarn, and thread mills	6.108E-08	2.365E-08	3.743E-08
484000	Truck transportation	6.091E-08	3.898E-08	2.193E-08
515200	Cable and other subscription programming	6.080E-08	4.302E-08	1.778E-08
333511	Industrial mold manufacturing	6.017E-08	3.479E-08	2.538E-08
331420	Copper rolling, drawing, extruding and alloying	5.994E-08	1.961E-08	4.033E-08
327993	Mineral wool manufacturing	5.986E-08	3.461E-08	2.525E-08
423A00	Other durable goods merchant wholesalers	5.986E-08	4.184E-08	1.801E-08

322299	All other converted paper product manufacturing	5.957E-08	2.744E-08	3.213E-08
112A00	Animal production, except cattle and poultry and eggs	5.950E-08	3.959E-08	1.991E-08
212310	Stone mining and quarrying	5.937E-08	3.900E-08	2.037E-08
336500	Railroad rolling stock manufacturing	5.910E-08	1.414E-08	4.496E-08
623A00	Nursing and community care facilities	5.879E-08	4.033E-08	1.846E-08
335222	Household refrigerator and home freezer manufacturing	5.859E-08	3.384E-08	2.475E-08
335210	Small electrical appliance manufacturing	5.854E-08	3.348E-08	2.506E-08
333111	Farm machinery and equipment manufacturing	5.838E-08	2.129E-08	3.709E-08
486000	Pipeline transportation	5.831E-08	4.475E-08	1.356E-08
327910	Abrasive product manufacturing	5.778E-08	3.816E-08	1.962E-08
711100	Performing arts companies	5.763E-08	4.273E-08	1.490E-08
812900	Other personal services	5.741E-08	4.315E-08	1.426E-08
311910	Snack food manufacturing	5.734E-08	1.913E-08	3.821E-08
336999	All other transportation equipment manufacturing	5.725E-08	1.899E-08	3.826E-08
323110	Printing	5.696E-08	3.232E-08	2.464E-08
327999	Miscellaneous nonmetallic mineral products	5.694E-08	3.125E-08	2.569E-08
327200	Glass and glass product manufacturing	5.655E-08	2.964E-08	2.691E-08
335911	Storage battery manufacturing	5.648E-08	3.204E-08	2.445E-08
813B00	Civic, social, professional, and similar organizations	5.636E-08	3.843E-08	1.793E-08
33299A	Ammunition, arms, ordnance, and accessories manufacturing	5.626E-08	2.992E-08	2.634E-08
322220	Paper Bag and Coated and Treated Paper Manufacturing	5.605E-08	2.376E-08	3.229E-08
336370	Motor vehicle metal stamping	5.574E-08	2.455E-08	3.119E-08
336320	Motor vehicle electrical and electronic equipment manufacturing	5.556E-08	1.918E-08	3.638E-08
33399B	Fluid power process machinery	5.555E-08	2.903E-08	2.652E-08
333316	Photographic and photocopying equipment manufacturing	5.552E-08	3.364E-08	2.188E-08
326190	Other plastics product manufacturing	5.536E-08	2.469E-08	3.067E-08
326150	Urethane and other foam product (except polystyrene) manufacturing	5.535E-08	2.530E-08	3.005E-08
331200	Steel product manufacturing from purchased steel	5.507E-08	2.608E-08	2.899E-08
561500	Travel arrangement and reservation services	5.501E-08	3.583E-08	1.918E-08

332119	Metal crown, closure, and other metal stamping (except automotive)	5.501E-08	2.635E-08	2.866E-08
339940	Office supplies (except paper) manufacturing	5.464E-08	2.969E-08	2.495E-08
1111B0	Grain farming	5.434E-08	1.127E-08	4.307E-08
312130	Wineries	5.428E-08	1.844E-08	3.585E-08
111200	Vegetable and melon farming	5.419E-08	2.456E-08	2.963E-08
322110	Pulp mills	5.390E-08	1.107E-08	4.284E-08
332410	Power boiler and heat exchanger manufacturing	5.380E-08	2.371E-08	3.009E-08
424400	Grocery and related product wholesalers	5.379E-08	3.421E-08	1.958E-08
336112	Light truck and utility vehicle manufacturing	5.359E-08	5.547E-09	4.804E-08
333612	Speed changer, industrial high-speed drive, and gear manufacturing	5.348E-08	2.492E-08	2.856E-08
448000	Clothing and clothing accessories stores	5.336E-08	3.528E-08	1.808E-08
325910	Printing ink manufacturing	5.315E-08	2.478E-08	2.837E-08
33291A	Valve and fittings other than plumbing	5.314E-08	2.272E-08	3.042E-08
311119	Other animal food manufacturing	5.299E-08	1.159E-08	4.140E-08
311111	Dog and cat food manufacturing	5.261E-08	1.446E-08	3.815E-08
322210	Paperboard container manufacturing	5.255E-08	1.800E-08	3.454E-08
561900	Other support services	5.244E-08	3.121E-08	2.124E-08
326110	Plastics packaging materials and unlaminated film and sheet manufacturing	5.241E-08	2.384E-08	2.857E-08
335991	Carbon and graphite product manufacturing	5.229E-08	3.012E-08	2.218E-08
335313	Switchgear and switchboard apparatus manufacturing	5.224E-08	2.509E-08	2.715E-08
711200	Spectator sports	5.202E-08	3.570E-08	1.632E-08
2123A0	Other nonmetallic mineral mining and quarrying	5.198E-08	3.399E-08	1.799E-08
446000	Health and personal care stores	5.196E-08	3.890E-08	1.306E-08
333414	Heating equipment (except warm air furnaces) manufacturing	5.158E-08	2.504E-08	2.655E-08
332200	Cutlery and handtool manufacturing	5.158E-08	2.905E-08	2.253E-08
311230	Breakfast cereal manufacturing	5.144E-08	1.511E-08	3.633E-08
333613	Mechanical power transmission equipment manufacturing	5.091E-08	2.495E-08	2.597E-08
333413	Industrial and commercial fan and blower and air purification equipment manufacturing	5.068E-08	1.956E-08	3.112E-08
314110	Carpet and rug mills	5.045E-08	1.486E-08	3.559E-08

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333120	Construction machinery manufacturing	5.030E-08	1.668E-08	3.362E-08
332720	Turned product and screw, nut, and bolt manufacturing	5.019E-08	2.021E-08	2.998E-08
332500	Hardware manufacturing	5.011E-08	1.873E-08	3.139E-08
333618	Other engine equipment manufacturing	5.007E-08	5.642E-09	4.443E-08
333991	Power-driven handtool manufacturing	4.968E-08	2.116E-08	2.853E-08
335920	Communication and energy wire and cable manufacturing	4.931E-08	1.237E-08	3.694E-08
336120	Heavy duty truck manufacturing	4.930E-08	5.870E-09	4.343E-08
334510	Electromedical and electrotherapeutic apparatus manufacturing	4.920E-08	4.058E-08	8.618E-09
424A00	Other nondurable goods merchant wholesalers	4.907E-08	3.197E-08	1.710E-08
33399A	Other general purpose machinery manufacturing	4.823E-08	1.913E-08	2.910E-08
332430	Metal can, box, and other metal container (light gauge) manufacturing	4.815E-08	1.513E-08	3.302E-08
33131B	Aluminum product manufacturing from purchased aluminum	4.750E-08	1.289E-08	3.461E-08
511120	Periodical Publishers	4.740E-08	3.237E-08	1.503E-08
322291	Sanitary paper product manufacturing	4.692E-08	1.288E-08	3.404E-08
335930	Wiring device manufacturing	4.690E-08	2.428E-08	2.262E-08
311225	Fats and oils refining and blending	4.677E-08	6.572E-09	4.020E-08
33391A	Pump and pumping equipment manufacturing	4.664E-08	1.621E-08	3.043E-08
812200	Death care services	4.663E-08	4.048E-08	6.144E-09
333130	Mining and oil and gas field machinery manufacturing	4.653E-08	1.477E-08	3.176E-08
541920	Photographic services	4.628E-08	3.131E-08	1.497E-08
325510	Paint and coating manufacturing	4.627E-08	1.895E-08	2.732E-08
333912	Air and gas compressor manufacturing	4.626E-08	1.495E-08	3.131E-08
335221	Household cooking appliance manufacturing	4.595E-08	1.952E-08	2.643E-08
33441A	Other electronic component manufacturing	4.583E-08	2.878E-08	1.705E-08
323120	Support activities for printing	4.526E-08	2.531E-08	1.995E-08
3259A0	All other chemical product and preparation manufacturing	4.512E-08	1.972E-08	2.540E-08
811200	Electronic and precision equipment repair and maintenance	4.496E-08	3.249E-08	1.246E-08
333314	Optical instrument and lens manufacturing	4.486E-08	2.503E-08	1.983E-08
327310	Cement manufacturing	4.476E-08	1.976E-08	2.500E-08

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333993	Packaging machinery manufacturing	4.454E-08	1.869E-08	2.585E-08
332991	Ball and roller bearing manufacturing	4.421E-08	1.929E-08	2.493E-08
322130	Paperboard mills	4.363E-08	6.310E-09	3.732E-08
335312	Motor and generator manufacturing	4.325E-08	1.467E-08	2.858E-08
333318	Other commercial and service industry machinery manufacturing	4.309E-08	1.820E-08	2.488E-08
454000	Nonstore retailers	4.291E-08	3.029E-08	1.262E-08
311224	Soybean and other oilseed processing	4.276E-08	7.136E-09	3.562E-08
322120	Paper mills	4.256E-08	7.952E-09	3.461E-08
333415	Air conditioning, refrigeration, and warm air heating equipment manufacturing	4.237E-08	1.387E-08	2.850E-08
325520	Adhesive manufacturing	4.234E-08	1.662E-08	2.572E-08
326160	Plastics bottle manufacturing	4.230E-08	1.370E-08	2.860E-08
221300	Water, sewage and other systems	4.229E-08	1.673E-08	2.556E-08
311221	Wet corn milling	4.225E-08	4.839E-09	3.741E-08
331313	Alumina refining and primary aluminum production	4.217E-08	1.112E-08	3.105E-08
325610	Soap and cleaning compound manufacturing	4.128E-08	1.647E-08	2.481E-08
212100	Coal mining	4.114E-08	2.439E-08	1.674E-08
335314	Relay and industrial control manufacturing	4.108E-08	1.463E-08	2.645E-08
336991	Motorcycle, bicycle, and parts manufacturing	4.092E-08	1.745E-08	2.347E-08
812100	Personal care services	4.077E-08	2.865E-08	1.212E-08
336992	Military armored vehicle, tank, and tank component manufacturing	4.063E-08	1.414E-08	2.649E-08
335999	All other miscellaneous electrical equipment and component manufacturing	4.059E-08	1.518E-08	2.541E-08
339116	Dental laboratories	4.032E-08	2.313E-08	1.719E-08
1121A0	Beef cattle ranching and farming, including feedlots and dual-purpose ranching and farming	4.010E-08	7.344E-09	3.276E-08
311930	Flavoring syrup and concentrate manufacturing	4.008E-08	1.186E-08	2.822E-08
339115	Ophthalmic goods manufacturing	4.002E-08	2.368E-08	1.634E-08
333611	Turbine and turbine generator set units manufacturing	3.986E-08	7.587E-09	3.227E-08
325130	Synthetic dye and pigment manufacturing	3.945E-08	1.841E-08	2.104E-08
33641A	Propulsion units and parts for space vehicles and guided missiles	3.932E-08	2.507E-08	1.425E-08
541400	Specialized design services	3.924E-08	2.911E-08	1.013E-08

339910	Jewelry and silverware manufacturing	3.910E-08	1.613E-08	2.297E-08
325310	Fertilizer manufacturing	3.898E-08	1.348E-08	2.550E-08
325120	Industrial gas manufacturing	3.893E-08	1.981E-08	1.913E-08
423100	Motor vehicle and motor vehicle parts and supplies	3.889E-08	2.051E-08	1.838E-08
324122	Asphalt shingle and coating materials manufacturing	3.888E-08	1.957E-08	1.932E-08
517A00	Satellite, telecommunications resellers, and all other telecommunications	3.879E-08	2.369E-08	1.510E-08
5416A0	Environmental and other technical consulting services	3.841E-08	2.680E-08	1.160E-08
515100	Radio and television broadcasting	3.793E-08	1.986E-08	1.807E-08
325620	Toilet preparation manufacturing	3.782E-08	1.647E-08	2.134E-08
621600	Home health care services	3.775E-08	2.557E-08	1.218E-08
331410	Nonferrous Metal (except Aluminum) Smelting and Refining	3.750E-08	9.398E-09	2.811E-08
811100	Automotive repair and maintenance	3.714E-08	1.933E-08	1.782E-08
21311A	Other support activities for mining	3.645E-08	2.004E-08	1.641E-08
532400	Commercial and industrial machinery and equipment rental and leasing	3.629E-08	1.865E-08	1.764E-08
423800	Machinery, equipment, and supplies	3.607E-08	2.013E-08	1.593E-08
423400	Professional and commercial equipment and supplies	3.605E-08	2.291E-08	1.313E-08
336413	Other aircraft parts and auxiliary equipment manufacturing	3.554E-08	1.411E-08	2.143E-08
519130	Internet publishing and broadcasting and Web search portals	3.544E-08	1.765E-08	1.778E-08
325320	Pesticide and other agricultural chemical manufacturing	3.508E-08	9.864E-09	2.522E-08
334290	Other communications equipment manufacturing	3.455E-08	2.147E-08	1.308E-08
3252A0	Synthetic rubber and artificial and synthetic fibers and filaments manufacturing	3.452E-08	9.165E-09	2.536E-08
2122A0	Iron, gold, silver, and other metal ore mining	3.448E-08	1.349E-08	2.099E-08
339113	Surgical appliance and supplies manufacturing	3.429E-08	1.412E-08	2.017E-08
621200	Offices of dentists	3.391E-08	2.103E-08	1.287E-08
1111A0	Oilseed farming	3.375E-08	8.515E-09	2.523E-08
561200	Facilities support services	3.362E-08	1.188E-08	2.175E-08
813100	Religious organizations	3.360E-08	4.917E-09	2.869E-08
611A00	Junior colleges, colleges, universities, and professional schools	3.330E-08	2.234E-08	1.097E-08
325180	Other Basic Inorganic Chemical Manufacturing	3.314E-08	1.164E-08	2.151E-08

325211	Plastics material and resin manufacturing	3.294E-08	8.050E-09	2.489E-08
325190	Other basic organic chemical manufacturing	3.286E-08	5.128E-09	2.773E-08
5310RE	Other real estate	3.248E-08	4.193E-09	2.829E-08
333242	Semiconductor machinery manufacturing	3.200E-08	7.171E-09	2.483E-08
334118	Computer terminals and other computer peripheral equipment manufacturing	3.153E-08	1.424E-08	1.730E-08
482000	Rail transportation	3.143E-08	1.206E-08	1.937E-08
621100	Offices of physicians	3.105E-08	1.663E-08	1.442E-08
312140	Distilleries	3.103E-08	6.548E-09	2.449E-08
492000	Couriers and messengers	3.076E-08	9.685E-09	2.108E-08
331110	Iron and steel mills and ferroalloy manufacturing	3.068E-08	1.955E-09	2.873E-08
713200	Gambling industries (except casino hotels)	3.050E-08	1.034E-08	2.016E-08
212230	Copper, nickel, lead, and zinc mining	3.001E-08	1.164E-08	1.837E-08
512100	Motion picture and video industries	2.965E-08	1.612E-08	1.353E-08
339112	Surgical and medical instrument manufacturing	2.965E-08	1.314E-08	1.651E-08
622000	Hospitals	2.931E-08	8.606E-09	2.070E-08
324121	Asphalt paving mixture and block manufacturing	2.927E-08	7.201E-09	2.207E-08
221100	Electric power generation, transmission, and distribution	2.833E-08	1.341E-08	1.492E-08
532100	Automotive equipment rental and leasing	2.807E-08	1.263E-08	1.544E-08
423600	Household appliances and electrical and electronic goods	2.738E-08	1.110E-08	1.628E-08
511130	Book publishers	2.714E-08	1.016E-08	1.699E-08
334418	Printed circuit assembly (electronic assembly) manufacturing	2.677E-08	1.023E-08	1.654E-08
334515	Electricity and signal testing instruments manufacturing	2.669E-08	1.084E-08	1.585E-08
334517	Irradiation apparatus manufacturing	2.662E-08	1.236E-08	1.426E-08
334513	Industrial process variable instruments manufacturing	2.660E-08	1.310E-08	1.351E-08
325411	Medicinal and botanical manufacturing	2.643E-08	1.384E-08	1.259E-08
336411	Aircraft manufacturing	2.641E-08	9.172E-09	1.724E-08
491000	Postal service	2.639E-08	5.700E-09	2.069E-08
213111	Drilling oil and gas wells	2.616E-08	1.175E-08	1.441E-08
334112	Computer storage device manufacturing	2.481E-08	1.247E-08	1.234E-08

324190	Other petroleum and coal products manufacturing	2.480E-08	6.194E-09	1.861E-08
518200	Data processing, hosting, and related services	2.447E-08	3.669E-09	2.080E-08
525000	Funds, trusts, and other financial vehicles	2.376E-08	6.042E-09	1.771E-08
541300	Architectural, engineering, and related services	2.341E-08	8.583E-09	1.483E-08
811300	Commercial and industrial machinery and equipment repair and maintenance	2.316E-08	7.046E-09	1.611E-08
611100	Elementary and secondary schools	2.287E-08	1.178E-08	1.109E-08
336414	Guided missile and space vehicle manufacturing	2.280E-08	5.748E-09	1.705E-08
325413	In-vitro diagnostic substance manufacturing	2.267E-08	1.148E-08	1.119E-08
33451A	Watch, clock, and other measuring and controlling device manufacturing	2.251E-08	1.369E-08	8.823E-09
814000	Private households	2.218E-08	2.218E-08	0.000E+00
221200	Natural gas distribution	2.201E-08	8.454E-09	1.355E-08
541800	Advertising, public relations, and related services	2.187E-08	4.679E-09	1.719E-08
561100	Office administrative services	2.171E-08	6.260E-09	1.545E-08
425000	Wholesale electronic markets and agents and brokers	2.033E-08	1.424E-08	6.088E-09
336412	Aircraft engine and engine parts manufacturing	2.032E-08	5.809E-09	1.451E-08
424200	Drugs and druggists' sundries	1.974E-08	3.813E-09	1.593E-08
517210	Wireless telecommunications carriers (except satellite)	1.959E-08	2.354E-09	1.723E-08
334514	Totalizing fluid meter and counting device manufacturing	1.932E-08	1.223E-08	7.086E-09
5419A0	All other miscellaneous professional, scientific, and technical services	1.930E-08	7.776E-09	1.152E-08
522A00	Nondepository credit intermediation and related activities	1.907E-08	8.238E-09	1.084E-08
334516	Analytical laboratory instrument manufacturing	1.878E-08	9.115E-09	9.661E-09
541610	Management consulting services	1.864E-08	4.938E-09	1.370E-08
325110	Petrochemical manufacturing	1.861E-08	1.530E-09	1.708E-08
54151A	Other computer related services, including facilities management	1.851E-08	4.911E-09	1.360E-08
325412	Pharmaceutical preparation manufacturing	1.795E-08	7.154E-09	1.080E-08
550000	Management of companies and enterprises	1.776E-08	7.254E-09	1.051E-08
523900	Other financial investment activities	1.744E-08	2.310E-09	1.513E-08
711500	Independent artists, writers, and performers	1.739E-08	1.087E-08	6.515E-09
334210	Telephone apparatus manufacturing	1.695E-08	8.372E-09	8.578E-09



541700	Scientific research and development services	1.680E-08	1.266E-09	1.553E-08
324110	Petroleum refineries	1.659E-08	7.210E-10	1.587E-08
541512	Computer systems design services	1.643E-08	5.541E-09	1.089E-08
211000	Oil and gas extraction	1.638E-08	4.834E-09	1.155E-08
325414	Biological product (except diagnostic) manufacturing	1.566E-08	8.751E-09	6.912E-09
517110	Wired telecommunications carriers	1.566E-08	2.363E-09	1.330E-08
561300	Employment services	1.516E-08	6.988E-09	8.175E-09
312200	Tobacco product manufacturing	1.515E-08	2.390E-09	1.276E-08
533000	Lessors of nonfinancial intangible assets	1.513E-08	2.363E-09	1.277E-08
523A00	Securities and commodity contracts intermediation and brokerage	1.490E-08	4.390E-09	1.051E-08
511200	Software publishers	1.485E-08	6.899E-09	7.950E-09
424700	Petroleum and petroleum products	1.484E-08	6.734E-09	8.103E-09
541200	Accounting, tax preparation, bookkeeping, and payroll services	1.459E-08	5.920E-09	8.675E-09
334413	Semiconductor and related device manufacturing	1.435E-08	5.937E-09	8.409E-09
334220	Broadcast and wireless communications equipment	1.430E-08	5.277E-09	9.021E-09
52A000	Monetary authorities and depository credit intermediation	1.416E-08	4.509E-09	9.653E-09
541511	Custom computer programming services	1.356E-08	3.210E-09	1.035E-08
541100	Legal services	1.344E-08	2.458E-09	1.098E-08
S00500	Federal general government (defense)	1.300E-08	1.981E-10	1.280E-08
524200	Insurance agencies, brokerages, and related activities	1.281E-08	3.999E-09	8.807E-09
334511	Search, detection, and navigation instruments manufacturing	1.152E-08	4.395E-09	7.126E-09
5241XX	Insurance carriers, except direct life	1.007E-08	1.681E-09	8.391E-09
S00600	Federal general government (nondefense)	8.898E-09	3.086E-10	8.589E-09
531HST	Tenant-occupied housing	7.525E-09	5.962E-09	1.562E-09
524113	Direct life insurance carriers	6.904E-09	1.862E-09	5.042E-09
531HSO	Owner-occupied housing	6.137E-09	2.828E-12	6.134E-09
4200ID	Customs duties	0.000E+00	0.000E+00	0.000E+00

\*Details about uncertainty (confidence interval) can be found on GitHub (<https://github.com/ZhehanHuang/Occupational-health-calculation/tree/main/uncertainty>)

### **Section S5.3: Applicability of our approach to other countries**

In our study, all of the production processes and their supply chains were conducted within the United States. To test the method, we developed a more widely available globally, the relevant databases of workplace injuries in some developed countries were searched, and suggestions were provided based on their data characteristics and availability.

In our study, the developed CFs are estimated based on US nonfatal occupational data across industrial sectors and supply chains. For other developed countries, such as Canada and UK that have similar economic structures, productivity levels, and welfare systems<sup>16</sup>, we believe our CFs are reasonable proxies; however, our CFs may not be good proxies for developing countries (e.g., India). In addition, we also evaluated the applicability of our approach in other countries. To this end, we searched the occupational injury databases of other countries and discussed the potential applications of our approach based on their data characteristics and availability. We characterized the quality of occupational databases of other countries into three categories: 1) high; 2) medium; 3) low. For countries (e.g., Japan<sup>17</sup>, Australia<sup>18</sup>) with high-quality occupational databases, the injuries are reported by injury type and economic sectors as the US does. Therefore, our approach can be applied to those countries with the adjustment of duration and severity of reported injuries. For countries (e.g., countries in the European Union<sup>19</sup>, Canada<sup>20</sup>) with medium-quality of occupational injury databases, the injuries are reported by economic sectors, but only provide the number of total injuries without no information on different types of injuries. Our approach can still be applied to those countries but the developed CFs will be at a less granular level. For countries (e.g., Korea<sup>21</sup>, India) with low-quality occupational databases that do not disclose or lack publicly available statistics on worker

injuries, our approach cannot be applied due to data limitations. We have searched and summarized the occupational injury databases of other countries in Table S12.

**Table S12. Occupational data sources for other countries**

Country	Source	Data Classification		Website
		By Industry	By Injury or Illness	
Australia	Safe Work Australia	o	o	<a href="https://www.safeworkaustralia.gov.au/doc/key-work-health-and-safety-statistics-australia-2021">https://www.safeworkaustralia.gov.au/doc/key-work-health-and-safety-statistics-australia-2021</a>
Canada	Employer's Annual Hazardous Occurrence Report (EAHOR)	o	x	<a href="https://www.canada.ca/en/employment-social-development/services/health-safety/reports/2020-injuries.html#h2.06">https://www.canada.ca/en/employment-social-development/services/health-safety/reports/2020-injuries.html#h2.06</a>
Europe Union	Eurostat	o	x	<a href="https://ec.europa.eu/eurostat/databrowser/view/hsw_aw_nnasx/default/table?lang=en">https://ec.europa.eu/eurostat/databrowser/view/hsw_aw_nnasx/default/table?lang=en</a>
Finland	National Board of Labour Protection	o	x	<a href="https://pxdata.stat.fi/PXWeb/pxweb/en/StatFin/StatFin__ttap/?tablelist=true">https://pxdata.stat.fi/PXWeb/pxweb/en/StatFin/StatFin__ttap/?tablelist=true</a>
Japan	Japan Industrial Safety and Health Association	o	o	<a href="https://www.jisha.or.jp/english/statistics/index.html">https://www.jisha.or.jp/english/statistics/index.html</a>
Korea	Korea Occupational Safety and Health Agency (KOSHA)	-	-	<a href="https://kosha.or.kr/english/news/whatsNew.do?mode=view&amp;articleNo=55074&amp;article.offset=0&amp;articleLimit=10&amp;srSearchVal=injuries&amp;srSearchKey=article_title">https://kosha.or.kr/english/news/whatsNew.do?mode=view&amp;articleNo=55074&amp;article.offset=0&amp;articleLimit=10&amp;srSearchVal=injuries&amp;srSearchKey=article_title</a>

Note: “o” represents data is available, while “x” represents data is not available.

## References

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