Which Industries to Bail out First in Economic Recession? Ranking Industrial Sectors by the Power-of-Pull

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Abstract

Since the economic recession spread out in 2008, there have been intense debates on which industrial sectors should receive bail-out funds first from the government. A lot of criteria on the choice of industries for bail-out have been discussed and debated. This paper proposes a quantitative method to rank the Power-of-Pull of the industrial sectors, by analyzing the Input-Output table. The Power-of-Pull of an industrial sector indicates how much its unit change can relatively pull the output of the overall economy through the transactional linkages in the network of industrial sectors. Results from analyzing the United States input-output tables of multiple years show that the health care sector, governmental and public sectors and the motor vehicle sector have been constantly the most important industrial sectors by Power-of-Pull, and should be considered for receiving bailout funds with priority. In fact, the results confirm the industry emphases of the latest stimulus plan of Obama Administration in the United States.

KEY WORDS: Bail out, stimulus plan, network analysis, industry, input-output table, Power-of-Pull, the United States economy, health care, motor vehicle, IT, government

Introduction

Since the late 2008 when the economic rescission spread out widely and affected the economy of the United States and the world, there have been intense debates regarding the content and approach of the governmental bailout plans. The initial US $700 billion bail-out plan under Emergency Economic Stabilization Act of 2008 proposed by former Treasure Secretary Henry Paulson emphasized the assistance for mortgage, insurance and investment banks (Clark, 2008), but later the attention has been paid to industrial companies, in particularly the big three U.S. automotive manufacturers GM, Ford and Chrysler, which have been hit fatally by the declining automobile sales in economic downturn (Isidore, 2008; U.S. Congress, 2008; General Motors Corporation, 2009; Chrysler LLC, 2009). Not only auto industry has been hit, but also other industries, such as IT (Information Technologies). IBM proposed to President Barack Obama for bailing out IT sectors by arguing their strong economic "network effects" (Bulkekey, 2009) to the rest of the economy. This paper aims to provide an objective criteria, index and quantitative approach for indentifying which industrial sectors need to receive bailout first.

For this purpose, the first need is a criterion to determine the priority of each industrial sector for bailout funds from the government. In the debates on the automotive sector, the supporting arguments for bailout often include "too big to fail", "creating three million jobs", "pillar of the economy", "financial viability" (General Motors Corporation, 2009; Chrysler, 2009; Dash, 2008), etc. Most of these are centered on the scale or internal

performance of the industry. In this work, I propose the priority of an industrial sector to receive bailout funds to be made in accordance with the sector's economic impacts externalized to the entire economy. Such a criterion is neither determined by the sector's own size nor the sizes of its directly connected sectors, but its marginal ability to pull the outputs of all the other sectors which are either directly or indirectly connected to it. Based upon this criterion, I propose an approach that uses Input-Output tables to quantitatively rank the sectors, and indentify the key ones which deserve high priority to receive bailout funds from the government.

Since Leontief (1951), Input-Output tables have been used to compare the impacts of sectors to a given economy and identify the "key sectors" (Rasmussen, 1956; Morillas and Diaz, 2008). In particular, a strand of input-output analyses has attempted to use weighting factors and indexes according to the inter-sector network linkage patterns to compare sectors, and identify key sectors (Rasmussen, 1956; Chenery and Watanabe, 1958; Hirschman, 1958; Diamond, 1974; Laumas, 1976). Some of these researches shared similar metrics and methods used in general network analysis (Wasserman and Faust, 1994; Kilkenny and Nalbarte, 2002; Muñiz et al, 2008). However, the importance of a sector can be defined, and the network linkages between industrial sectors can be measured in different ways (Yotopoulos and Nugent, 1973, 1976; Boucher, 1976, Cardenete and Sancho, 2006; Morillas and Diaz, 2008; Muniz et al, 2008). Measurements need to be designed in accordance with the criteria chosen for specific situations and research purposes.

In this paper, I will introduce a network analysis approach that quantitatively evaluate such network effect of a sector -- the marginal ability of each sector to pull economic activities (e.g., output, job creation) in other sectors, and indentify the most important industrial sectors that can maximize the unit outcome of each cent of the bail-out fund for the entire economy. I applied this approach to the U.S. Input-Output tables, and each sector is ranked by a network-based metric. The results and analyses from this paper may provide insights for government decisions on the disposal of the bail-out funds.

Theory and Method

The central idea of this approach is: if one sector's dependents, i.e., those sectors supplying to it, are further highly depended by many other highly-depended sectors, this sector is regarded highly depended by the rest the economic network. I first define an abstract factor/rank for a sector's degree of being depended by the rest of the network generally. I tentatively call this factor/rank "Power-of-Pull". It indicates how much a sector can relatively pull the outputs of the overall economic network, rather than a subgroup of sectors directly connected to it. That is to say, one sector's Power-of-Pull depends on the Power-of-Pull of those who are pulled by it, while the Power-of-Pull of those who are pulled by it depends on the Power-of-Pull of those who are further pulled. This could be an infinite regress situation. So forth, such economic pulling influence is diffused and extended via network paths. To quantify this idea needs a little mathematics.

In a single step, examining the sectors which are just one hop from sector *i* in the network of *n* sectors, its Power-of-Pull, $P(i)$, is a function of the Power-of-Pull of the *n* sectors (including itself), which are linked directly or indirectly to *i*. That is,

$$\lambda P(i) = x_{1i}P(1) + x_{2i}P(2) + ...x_{ki}P(k)... + x_{ni}P(n) \quad (1)$$

where λ is a scaling constant, and x_{ki} is the dependence ratio of sector *k* on sector *i*. x_{ki} indicates the percentage of *k*'s output that is pulled by *i*. Practically, x_{ki} is calculated as the ratio of output of sector *k* that is consumed by sector *i*, over *k*'s total output, using the Use Table data (one kind of Input-Output tables) provided annually by the Bureau of Economic Analysis of the U.S. government. Input-Output table represents the economy as a network of industrial sectors (motor vehicle, electronics, health care, etc), which transact with each other. In a Use Table, cell (A, B) contains the value (in million dollars) that are produced by industry sector A and consumed by industry sector B. See a simple example Input-Output table in table 1.

(Table 1 about here)

Therefore, the dependence ratio x_{ki} can be derived by dividing each cell in row *k* by the sum of row *k*, i.e., the total output of sector *k*. Then we derive the dependence ratios shown in table 2.

(Table 2 about here)

Thus, if we take the *i*th column of the matrix in table 2, which contains entrees indicating all sectors' dependences on sector *i*'s use, we can multiply these entrees by the Power-of-

Pull of the other sectors in the whole network to obtain a linear combination measuring the Power-of-Pull of *i*. This is exactly how established formula (1) is established.

Thus, for the economy of *n* sectors, mathematically we have *n* linear equations like (1), all of which depend on and pull themselves, the $\{P(i)\}, i = 1, 2, ..., n$. So we have *n* linear equations with *n* unknowns. If we take the entire dependence ratio matrix, *X*, and put the set of Power-of-Pull indices into a vector $\boldsymbol{p} = [P(1), P(2), ..., P(n)]'$, we can write this system of equations as.

$$X' \boldsymbol{p} = \lambda \boldsymbol{p} \tag{2}$$

The focus now is to find the solution for $\boldsymbol{p}$. This is equivalent to finding the eigenvectors and eigenvalues for matrix X'. And, I propose to choose the principle eigenvector of X' as the Power-of-Pull ranks of the industrial sectors respectively, for two reasons: 1) our initial idea is just $\boldsymbol{p}$ is **strongly** determined by the Power-of-Pull of the group themselves, so large λ is preferred; 2) there is no multiplicity of the principal eigenvalue in our case.

Results and Analysis

This approach is applied to the 1998-2007 Use Tables after redefinitions at the summary level (http://www.bea.gov/industry/). The dependence ratio matrices are constructed based on the original tables, transposed them, found the principle eigenvector as $\boldsymbol{p}$, and ranked the industrial sectors according to their $\boldsymbol{p}$ (Power-of-Pull).

Table 3 shows the results of analyzing the network of 65 industrial sectors in 2007, without considering personal consumptions and exports. In this case, health care, government, and motor vehicle industries are ranked the top 3 because they have the largest Power-of-Pull in the economy. This indicates great potential system outcome from the investments into the health care sector, government spending, and the bailout to the motor vehicle industries. This seems to support President Obama's policy emphasis on heath care reform (Karl, et al, 2009; http://www.whitehouse.gov/agenda/health_care/, retrieved on March 12, 2009), the plan to stimulate economy by investing in public infrastructures and projects (Karl, et al, 2009), and his commitment to the automotive industry bailout (LaMonica, 2008).

(Table 3 about here)

Table 4 shows the results of analyzing the network of 65 industrial sectors plus considering payment as input and personal consumption as output of the sector of "labor". In this case, the labor sector has the largest Power-of-Pull, government stays as No.2 and construction moves up from No.4 to No.3. This indicates the stimulus plan with regard to personal tax reductions and returns is appropriate. Health care dropped to 11th. Motor vehicle sector dropped to 15th, but is still ranked the highest among all the manufacturing industry sectors.

(Table 4 about here)

Table 5 shows the results of analyzing the network of 65 industrial sectors plus labor sector, and exports as another sector. In this case, the labor sector and government are

still the top 2. However, exports replaced construction as the third. Motor vehicle sector's rank dropped again, but it is still ranked the highest among the manufacturing industrial sectors.

(Table 5 about here)

Among the three analysis settings discussed above, I prefer the 65-sector network that leaves out labor/consumption and export, because they are not real industrial sectors. With the use of 65-sector networks for multiple years, the changes of rank by Power-of-Pull of 8 selected major industrial sectors are compared over the past 8 years. Over time, the rank of motor vehicle moved down a little while health care has become more and more "powerful". It is surprising that the Power-of-Pull of the IT manufacturing sector has been decreasing continuously and rapidly over the past decade. This may be related to the extensive outsourcing of computer and electronics manufacturing to the East Asian countries and regions during that period of time, meanwhile the outsourcing of automobile manufacturing did not take place at a significant scale.

(Figure 1 about here)

Conclusions

In this paper, in order to identify the priorities of industrial sectors to receive bailout funds from the government, I propose a quantitative network-based metric and method to rank the Power-of-Pull of the industrial sectors, by analyzing the U.S. Input-Output tables.

The results presented in the foregoing sections have shown the strong Power-of-Pull network effects of the health care sector, the public and infrastructure sectors, and the motor vehicle sectors. This confirms the appropriateness of Obama administration's stimulus plan that has emphasized these sectors. Comparatively, the IT-related sectors have very limited Power-of-Pull in the economy. The IT sectors are consistently ranked lower than the motor vehicle sector, construction sector, etc. This indicates the weakness of the IBM argument on the "strong" "network effect" of IT sectors to the economy of the United States. In any case of the analyses, the financial/insurance sectors are ranked not very high. It indicates that, it might be a mistake if the government sends the largest portion of its limited bail-out funds to the banks and other financial institutions.

Furthermore, one of the beauties of this approach is that, it does not count the production volume or size of a sector, but its marginal influence to all the other sectors, which is quantified by holistically considering the entire network of sectors. For instance, the motor vehicle sector needs bail-out, but the rationale is not because it is large, but because it has strong Power-of-Pull network effect to the rest of economy. Any penny invested here will be able to pull the rest of the economy much better than the IT sectors.

This approach can be also applied to analyzing detail-level Input-Output tables, other countries, and the international trade networks.

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Appendix

Table 1: Transaction Values in an Example 3-Sector Economy

	Inputs to Sector 1	Inputs to Sector 2	Inputs to Sector 3
Sector 1	5	15	2
Sector 2	10	20	10
Sector 3	10	15	5

Table 2: Dependence Ratios in an Example 3-Sector Economy

	Inputs to Sector 1	Inputs to Sector 2	Inputs to Sector 3
Sector 1	5/22	15/22	2/22
Sector 2	10/40	20/40	10/40
Sector 3	10/30	15/30	5/30

Table 3: Rank by Power-of-Pull of 65 Industrial Sectors in the U.S., 2007

Rank	Industrial Sector	Network Effect (Max Eigenvalue = 0.8470)
1	Ambulatory health care services	1.0000
2	State and local general government	0.5498
3	Motor vehicles, bodies and trailers, and parts	0.2462
4	Construction	0.2153
5	Food and beverage and tobacco products	0.2111
6	Real estate	0.2088
7	Federal general government	0.1772
8	Food services and drinking places	0.1620
9	Insurance carriers and related activities	0.1615
10	Miscellaneous professional, scientific and technical services	0.1614
11	Other services, except government	0.1492
12	Broadcasting and telecommunications	0.1347
13	Hospitals and nursing and residential care facilities	0.1343
14	Retail trade	0.1126
15	Wholesale trade	0.0925
16	Chemical products	0.0849
17	Computer and electronic products	0.0744
18	Federal Reserve banks, credit intermediation, and related activities	0.0733

19	Administrative and support services	0.0707
20	Publishing industries (includes software)	0.0603
21	Petroleum and coal products	0.0573
22	Farms	0.0569
23	Truck transportation	0.0559
24	Securities, commodity contracts, and investments	0.0554
25	Management of companies and enterprises	0.0533
26	Rental and leasing services and lessors of intangible assets	0.0513
27	State and local government enterprises	0.0456
28	Machinery	0.0449
29	Other transportation equipment	0.0420
30	Information and data processing services	0.0415
31	Plastics and rubber products	0.0323
32	Fabricated metal products	0.0318
33	Oil and gas extraction	0.0298
34	Educational services	0.0284
35	Utilities	0.0282
36	Primary metals	0.0272
37	Paper products	0.0253
38	Computer systems design and related services	0.0249
39	Legal services	0.0239
40	Funds, trusts, and other financial vehicles	0.0206
41	Miscellaneous manufacturing	0.0203
42	Social assistance	0.0194
43	Air transportation	0.0190
44	Accommodation	0.0168
45	Motion picture and sound recording industries	0.0162
46	Waste management and remediation services	0.0151
47	Federal government enterprises	0.0150
48	Nonmetallic mineral products	0.0150
49	Performing arts, spectator sports, museums, and related activities	0.0143
50	Support activities for mining	0.0142
51	Amusements, gambling, and recreation industries	0.0138
52	Printing and related support activities	0.0133
53	Electrical equipment, appliances, and components	0.0122
54	Textile mills and textile product mills	0.0120
55	Wood products	0.0115
56	Furniture and related products	0.0107
57	Mining, except oil and gas	0.0095
58	Other transportation and support activities	0.0091
59	Rail transportation	0.0069
60	Water transportation	0.0053
61	Pipeline transportation	0.0051
62	Apparel and leather and allied products	0.0049
63	Transit and ground passenger transportation	0.0039
64	Forestry, fishing, and related activities	0.0038
65	Warehousing and storage	0.0033

Table 4: Rank Power-of-Pull of 66 Sectors in the U.S., 2007 (Including labor/personal consumption)

Rank	Industrial Sectors	Network Effect (Max Eigenvalue = 0.926)
1	Labor Payment/Personal consumption expenditures	1.0000
2	State and local general government	0.2262
3	Construction	0.1480
4	Federal general government	0.1204
5	Retail trade	0.1170
6	Miscellaneous professional, scientific and technical services	0.1133
7	Wholesale trade	0.1076
8	Real estate	0.0958
9	Other services, except government	0.0837
10	Hospitals and nursing and residential care facilities	0.0825
11	Ambulatory health care services	0.0753
12	Food and beverage and tobacco products	0.0684
13	Broadcasting and telecommunications	0.0662
14	Administrative and support services	0.0658
15	Motor vehicles, bodies and trailers, and parts	0.0618
16	Food services and drinking places	0.0617
17	Federal Reserve banks, credit intermediation, and related activities	0.0612
18	Insurance carriers and related activities	0.0591
19	Securities, commodity contracts, and investments	0.0564
20	Computer and electronic products	0.0547
21	Management of companies and enterprises	0.0518
22	Chemical products	0.0467
23	Computer systems design and related services	0.0369
24	Machinery	0.0366
25	State and local government enterprises	0.0359
26	Publishing industries (includes software)	0.0349
27	Petroleum and coal products	0.0336
28	Other transportation equipment	0.0317
29	Fabricated metal products	0.0306
30	Truck transportation	0.0276
31	Legal services	0.0263
32	Rental and leasing services and lessors of intangible assets	0.0258
33	Educational services	0.0253
34	Utilities	0.0232
35	Oil and gas extraction	0.0222
36	Information and data processing services	0.0208
37	Primary metals	0.0197
38	Plastics and rubber products	0.0191
39	Farms	0.0187
40	Federal government enterprises	0.0167
41	Social assistance	0.0164
42	Paper products	0.0163
43	Miscellaneous manufacturing	0.0153
44	Funds, trusts, and other financial vehicles	0.0151
45	Air transportation	0.0135

46	Other transportation and support activities	0.0130
47	Accommodation	0.0128
48	Amusements, gambling, and recreation industries	0.0123
49	Support activities for mining	0.0113
50	Nonmetallic mineral products	0.0112
51	Printing and related support activities	0.0110
52	Electrical equipment, appliances, and components	0.0109
53	Motion picture and sound recording industries	0.0101
54	Wood products	0.0100
55	Performing arts, spectator sports, museums, and related activities	0.0093
56	Furniture and related products	0.0081
57	Mining, except oil and gas	0.0080
58	Waste management and remediation services	0.0070
59	Textile mills and textile product mills	0.0064
60	Rail transportation	0.0059
61	Warehousing and storage	0.0055
62	Forestry, fishing, and related activities	0.0050
63	Pipeline transportation	0.0037
64	Water transportation	0.0034
65	Transit and ground passenger transportation	0.0033
66	Apparel and leather and allied products	0.0030

Table 5: Rank by Power-of-Pull of 67 Sectors in the U.S., 2007 (Including labor/personal consumption and exports)

Rank	Industrial Sectors	Network Effect (Max Eigenvalue=0.8654)
1	Labor Payment/Personal consumption expenditures	1.0000
2	State and local general government	0.2313
3	Exports of goods and services	0.1511
4	Construction	0.1456
5	Retail trade	0.1195
6	Miscellaneous professional, scientific and technical services	0.1160
7	Federal general government	0.1135
8	Wholesale trade	0.1097
9	Real estate	0.0986
10	Hospitals and nursing and residential care facilities	0.0841
11	Other services, except government	0.0810
12	Ambulatory health care services	0.0770
13	Administrative and support services	0.0673
14	Broadcasting and telecommunications	0.0666
15	Food and beverage and tobacco products	0.0655
16	Federal Reserve banks, credit intermediation, and related activities	0.0626
17	Food services and drinking places	0.0623
18	Insurance carriers and related activities	0.0620
19	Securities, commodity contracts, and investments	0.0577
20	Management of companies and enterprises	0.0533
21	Motor vehicles, bodies and trailers, and parts	0.0520
22	Computer and electronic products	0.0497

23	Chemical products	0.0441
24	Computer systems design and related services	0.0378
25	State and local government enterprises	0.0361
26	Publishing industries (includes software)	0.0345
27	Petroleum and coal products	0.0332
28	Machinery	0.0327
29	Fabricated metal products	0.0297
30	Legal services	0.0273
31	Truck transportation	0.0271
32	Educational services	0.0259
33	Rental and leasing services and lessors of intangible assets	0.0259
34	Other transportation equipment	0.0237
35	Utilities	0.0230
36	Oil and gas extraction	0.0215
37	Information and data processing services	0.0202
38	Primary metals	0.0185
39	Plastics and rubber products	0.0179
40	Farms	0.0177
41	Federal government enterprises	0.0171
42	Social assistance	0.0167
43	Paper products	0.0156
44	Funds, trusts, and other financial vehicles	0.0150
45	Miscellaneous manufacturing	0.0147
46	Accommodation	0.0131
47	Other transportation and support activities	0.0130
48	Air transportation	0.0128
49	Amusements, gambling, and recreation industries	0.0127
50	Nonmetallic mineral products	0.0109
51	Support activities for mining	0.0107
52	Printing and related support activities	0.0107
53	Electrical equipment, appliances, and components	0.0103
54	Motion picture and sound recording industries	0.0099
55	Wood products	0.0099
56	Performing arts, spectator sports, museums, and related activities	0.0096
57	Furniture and related products	0.0080
58	Mining, except oil and gas	0.0074
59	Waste management and remediation services	0.0071
60	Textile mills and textile product mills	0.0061
61	Warehousing and storage	0.0057
62	Rail transportation	0.0055
63	Forestry, fishing, and related activities	0.0050
64	Pipeline transportation	0.0036
65	Transit and ground passenger transportation	0.0033
66	Water transportation	0.0032
67	Apparel and leather and allied products	0.0029

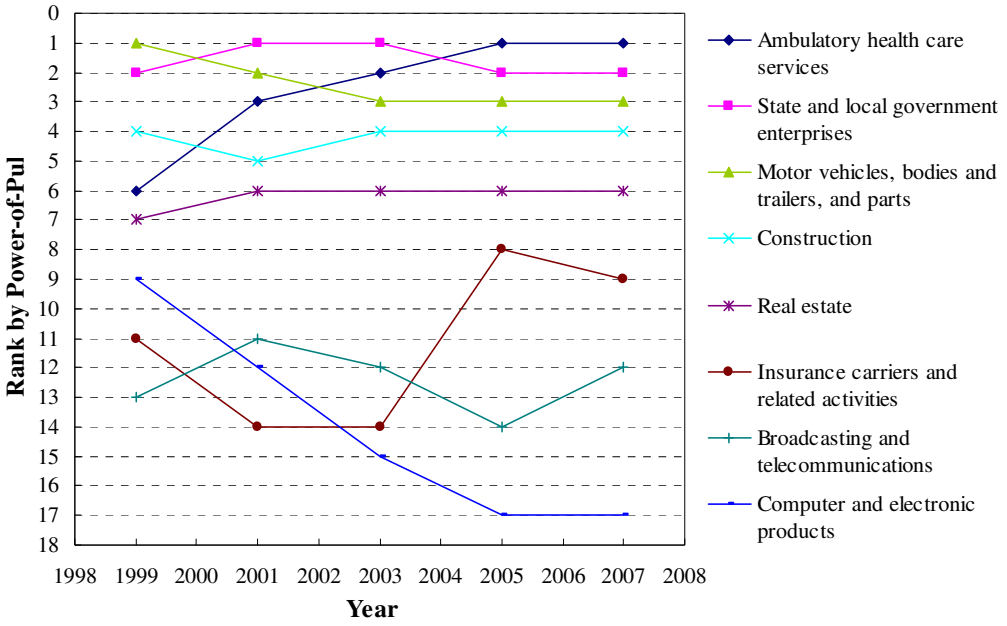

Figure 1. Power-of-Pull rank changes of selected industrial sectors in past 8 years