Data Appendix to "Economic Growth in the Information Age"

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A. Introduction and Classifications

We begin with a brief reminder of the recent history of industry level accounts in the U.S. The NAICS was adopted in 1997 to replace the Standard Industrial Classification (SIC) system; the SIC was the basis on the industry productivity measures in Jorgenson, Gollop and Fraumeni (1987), Jorgenson, Ho and Stiroh (2005) and Jorgenson, Ho, Samuels and Stiroh (2007). The first version of GDP by industry in NAICS in the National Accounts (NIPA) was released in March 2004 with data covering 1998-2002 for 65 industries. In that version of the NIPA, the data for 1948-86 was in the SIC(1972) system and in SIC(1987) for the 1987-2000 data. The BEA also provides gross output estimates for a more detailed set of industries but "does not include these detailed estimates in the published tables because their quality is significantly less than that of the higher-level aggregates in which they are included." For these unpublished tables, output data is provided for 426 industries (in NAICS-2002).

These early versions of the NAICS data for 1998 -2007 were used in Jorgenson, Ho and Samuels (2011) to generate a time series in NAICS for 1960-2007 by linking to the earlier SIC based input-output data used in Jorgenson, Ho, Samuels, Stiroh (2007). These will be referred to as JHS(2011) and JHSS(2007) below.

In the more recent release in December 2011, the BEA provided GDP-by-Industry estimates for 65 industries (in NAICS2002) back to 1977, and for 22 industry groups for the earlier period 1947-1976. These 65 industries are the same as those reported in the NIPAs in 2011. The estimates for 1987-2000 are described in Yuskavage and Pho (2004), and for 1947-86 in Yuskavage and Fahim-Nader (2005). The important innovation by the BEA was the estimation of a times series of Use and Make tables back to 1947 on a consistent NAICS classification. This series of tables covered the same 65 industries for 1963-1997, and for the 1947-62 period, they covered 46 industries. These were made by Mark Planting as a special assignment from the BEA.

We made use of these two main BEA series – the 1947-97 IO tables in NAICS estimated by Planting, and the annual IO tables for 1998-2010 from the BEA Industry Division – to estimate the inter-industry transactions and the value added for our industries. We also supplemented these data with information from the Bureau of Labor Statistics (BLS) and other sources.

The data for labor and capital accumulation was also changed over to NAICS during this period. There is unfortunately, no parallel official effort to convert the historical labor data from SIC to NAICS. The BEA investment data in the *Fixed Asset Accounts* provides an estimate of historical

investment by asset type in NAICS. As with the output accounts, these detailed investment data are not in the official publications "because they are less reliable than the higher level aggregates in which they are included."

The three sections of the rest of this appendix describes how we estimated the labor input, capital input and intermediate input for each industry from these primary data. We focus here on how we converted SIC based data into NAICS, the general methodology is given in JHS (2005).

We construct data for various sets of industries, each set designed to fulfill the aims of a particular study. At the most detailed level we identify 98 NAICS industries as listed in Table A1 in the column marked "DJA98". We then aggregate these to two other smaller sets of industries; BEA65 correspond to the industries in the BEA's time series of input-output accounts while DJA87 are the industries used in Jorgenson, Ho and Samuels (2013) with more detail on the Information Technology sectors.

Table A1. Industry classifications

	DJA98 Industry	NAICS		DJA87 Industry		DJA65 Industry
1	Farms	111, 112	1	Farms	1	Farms
2	Forestry and related activities	113:115 ex 1141	2	Forestry and related activities	2	Forestry fishing and related activities
3	Fishing	1141				
4	Oil and gas extraction	211	3	Oil and gas extraction	3	Oil and gas extraction
5	Coal mining	2121	4	Coal mining	4	Mining except oil and gas
6	Non-energy mining	2122, 2123	5	Non-energy mining		
7	Support activities for mining	2130	6	Support activities for mining	5	Support activities for mining
8	Electric power: generation; transmission; distribution	2211	7	Electric power: generation; transmission; distribution	6	Utilities
9	Natural gas distribution	2212	8	Natural gas distribution		
10	Water and sewage	2213	9	Water and sewage		
11	Construction	230	10	Construction	7	Construction
12	Wood products		11	Wood products	8	Wood products
13	Nonmetallic mineral products	327	12	Nonmetallic mineral products	9	Nonmetallic mineral products
14	Primary metals; iron and steel	3311, 3312	13	Primary metals; iron and steel	10	Primary metals
15	Primary metals; non-ferrous metals	3313:3315	14	Primary metals; non-ferrous metals		
16	Fabricated metal products	332	15	Fabricated metal products	11	Fabricated metal products
17	Machinery	333	16	Machinery	12	Machinery
18	Computer and electronic products	3341	17	Computer and peripheral equip mfg	13	Computer and electronic products
19	Telecommunication equipment	3342	18	Communications equipment mfg		
20	Radio and TV receivers	3343, 3346				
21	Electronic components and products	3344	19	Semiconductor and other Electronic component mfg		
22	Instruments	3345	20	Other electronic equipment		
23	Insulated wire	33592				
24	Other electrical machinery	335 ex 33592	21	Electrical equipment	14	Electrical equipment appliances and components
25	Motor vehicles and parts	3361:3363	22	Motor vehicles and parts	15	Motor vehicles bodies and trailers and parts

	DJA98 Industry	NAICS		DJA87 Industry		DJA65 Industry
26	Ships and boats	3366				
27	Aircraft and spacecraft	3364	23	Aircraft and spacecraft	16	Other transportation equipment
28	Other transportation equipment	3365, 3369	24	Other transportation equipment		
29	Furniture and related products	337	25	Furniture and related products	17	Furniture and related products
30	Medical equipment	3391				
31	Miscellaneous manufacturing	339 ex 3391	26	Miscellaneous manufacturing	18	Miscellaneous manufacturing
32	Food and beverage	311, 3121	27	Food and beverage	19	Food and beverage and tobacco products
33	Tobacco products	3122	28	Tobacco products		
34	Textile mills and textile product mills	313, 314	29	Textile mills and textile product mills	20	Textile mills and textile product mills
35	Apparel	315	30	Apparel	21	Apparel and leather and allied products
36	Leather and allied products	316	31	Leather and allied products		
37	Paper and paper products	322	32	Paper and paper products	22	Paper products
38	Printing and related support activities	323	33	Printing and related support activities	23	Printing and related support activities
39	Petroleum and coal products	324	34	Petroleum and coal products	24	Petroleum and coal products
40	Chemicals; excl pharma	325 ex 3254	35	Chemicals; excl pharma	25	Chemical products
41	Pharmaceuticals	3254	36	Pharmaceuticals		
42	Plastics and rubber products	326	37	Plastics and rubber products	26	Plastics and rubber products
43	Wholesale trade; durable	421	38	Wholesale trade	27	Wholesale Trade
44	Wholesale trade; nondurable	422				
45	Retail trade; motor vehicles	441	39	Retail trade; motor vehicles	28	Retail Trade
46	Retail trade; food	445	40	Retail trade; other		
47	Retail trade; general merchandise	452				
48	Retail trade; other	44,45 ex above				
49	Air transportation	481	41	Air transportation	29	Air transportation
50	Rail transportation	482	42	Rail transportation	30	Rail transportation
51	Water transportation	483	43	Water transportation	31	Water transportation
52	Truck transportation	484	44	Truck transportation	32	Truck transportation
53	Transit and ground passenger transportation	485	45	Transit and ground passenger transportation	33	Transit and ground passenger transportation

	DJA98 Industry	NAICS		DJA87 Industry		DJA65 Industry
54	Pipelines	486	46	Pipelines	34	Pipeline transportation
55	Other transportation and support activities	487:492	47	Other transportation and support activities	35	Other transportation and support activities
56	Warehousing and storage	493	48	Warehousing and storage	36	Warehousing and storage
57	Newspaper; periodical; book publishers	5111	49	Newspaper; periodical; book publishers	37	Publishing industries (includes software)
58	Software publishing	5112	50	Software publishing		
59	Motion picture and sound recording industries	512	51	Motion picture and sound recording industries	38	Motion picture and sound recording industries
60	Radio; TV; cable	515	52	Broadcasting	39	Broadcasting and telecommunications
61	Telecommunications	517	53	Telecommunications		
62	Information and data processing services	516, 518,519	54	Information and data processing services	40	Information and data processing services
63	Federal reserve banks; credit intermediation	521, 522	55	Federal reserve banks; credit intermediation	41	Federal Reserve banks credit intermediation and related activities
64	Securities; commodity contracts; investments	523	56	Securities; commodity contracts; investments	42	Securities commodity contracts and investments
65	Insurance carriers and related activities	524	57	Insurance carriers and related activities	43	Insurance carriers and related activities
66	Funds and trusts	525	58	Funds and trusts	44	Funds trusts and other financial vehicles
67	Real estate (rental)	531	59	Real Estate + OOH (intermediate only)	45	Real estate
68	Real estate (owner occupied)	ooh	60	OOH (VA only)		
69	Rental and leasing services; lessors of intangibles	532:533	61	Rental and leasing services; lessors of intangibles	46	Rental and leasing services and lessors of intangible assets
70	Legal services	5411	62	Legal services	47	Legal services
71	Computer systems design and related services	5415	63	Computer systems design and related services	48	Computer systems design and related services
72	Misc. professional; scientific; and technical services	541* ex 1,5,7	64	Misc. professional, scientific	49	Miscellaneous professional scientific and technical services
73	Scientific research and development; other prof.	5417				
74	Management of companies and enterprises	55	65	Management of companies and enterprises	50	Management of companies and enterprises
75	Administrative & support services	561	66	Administrative & support services	51	Administrative and support services
76	Waste management	562	67	Waste management	52	Waste management and remediation services
77	Educational services	61	68	Educational services	53	Educational services
78	Offices of physicians; dentists; other practitioners	6211:6213	69	Ambulatory health care services	54	Ambulatory health care services

	DJA98 Industry	NAICS		DJA87 Industry		DJA65 Industry
79	Outpatient care; medical laboratories; home health; etc	6214:6216				
80	Hospitals	622	70	Hospitals, nursing and resid care	55	Hospitals Nursing and residential care facilities
81	Nursing and residential care facilities	623				
82	Social assistance	624	71	Social assistance	56	Social assistance
83	Performating arts; spectator sports; museums	711, 712	72	Performing arts; spectator sports; museums	57	Performing arts spectator sports museums and related activities
84	Amusements and gambling	713	73	Amusements and gambling	58	Amusements gambling and recreation industries
85	Accommodations	721	74	Accommodations	59	Accommodation
86	Food services and drinking places	722	75	Food services and drinking places	60	Food services and drinking places
87	Other services (repair; personal svc; organizations)	811:813	76	Automobile repair	61	Other services except government
			77	Other services (repair; personal svc; organizations)		
88	Private households	814	78	Private households		
89	Federal gen govt excl health		79	Federal gen govt excl health	62	Federal General government
90	Federal govt enterprises		81	Federal gov enterprises (ex electric)	63	Federal Government enterprises
			82	Fed gov enterp; electric utilities		
91	Federal govt hospitals		80	Fed gov health		
92	S&L govt hospitals		85	S&L gov health	65	S&L General Government
93	Fed other health					
94	S&L other health					
95	S&L education		86	S&L education		
96	S&L excl health and edu		87	S&L excl health and edu		
97	S&L govt enterprises		83	S&L gov enterprises (ex electric)	64	S&L Government enterprises
			84	S&L gov enterp; electric utilities		
98	Military					

A.1. Labor input by NAICS Industries

Our methodology for constructing labor input measures at the industry level is described in detail in Jorgenson, Ho and Stiroh (Chapter 6, 2005). That updates the labor accounts for 51 industries for 1947-1979 given in Jorgenson, Gollop and Fraumeni (1987), and reports the labor indices for 44 SIC industries for the period 1977-2000. In this section we first summarize the labor index formulas and then describe the construction of data in NAICS for the most recent period, beginning when the Current Population Survey started using NAICS in 2003. Then we discuss how the pervious data set in SIC is bridged to the NAICS.

A.1.1 Methodology

The labor input for industry *j* is given by a Tornqvist index of the hours worked by different worker types:

$$\text{(A.1)} \quad \Delta \ln L_{jt} = \sum_l \bar{v}_{ljt} \Delta \ln H_{ljt}$$

where H_{ijt} is the number of hours worked by workers of type *l* in *j* at time *t*, and $\bar{v}_{ljt}$ are the value share weights:

$$\text{(A.2)} \quad \bar{v}_{ljt} = \tfrac{1}{2}[v_{ljt} + v_{lj,t-1}],$$

$$\text{(A.3)} \quad v_{lj} = \frac{P_{L,lj} H_{lj}}{\sum_l P_{L,lj} H_{lj}}$$

The demographic groups of labor that are distinguished are sex, age, class of worker and educational attainment; these are given in Table A2. The industry groups identified are those given in the column marked DJA98Naics in Table A1.

We define the index of labor quality (or the index of labor composition) as the ratio of labor input to total hours:

$$\text{(A.4)} \quad Q^L_{jt} = \frac{L_{jt}}{H_{jt}}; \qquad H_j = \sum_l H_{lj}$$

To implement equation A.1 we need to compute the hourly labor cost for each type of worker, $P_{L,lj}$, and the total annual hours worked of each type, H_{lj}. The annual hours worked are computed by estimating the number of workers of each type (E to denote employment), their average hours per week (h) and their weeks worked per year (W):

(A.5) $H_{ljt} = E_{ljt} h_{ljt} W_{ljt}$

The price of labor to the employer is derived by estimating the total compensation per hour worked. This is derived by first estimating the wages earned and then scaling to total compensation which include fringe benefits and payroll taxes paid by the employer that is not reported for the income question in the population survey. The hourly compensation matrix is denoted as C_{ljt}

In the following sections we describe how we estimate these matrices for employment, weekly hours, annual weeks and compensation. These E_{ljt}, h_{ljt}, W_{ljt} and C_{ljt} matrices are derived from the decennial Census and annual Current Population Survey (CPS) as explained in JHS (2005). They are scaled to equal the total employment and total compensation by industry in the National Accounts, with a special adjustment for self-employed and unpaid workers. In the next section we begin by describing how the CPS for 2003-2010 is used.

When we need to be explicit, we avoid the E_{ljt} abbreviation and denote the employment in type sex *s*, class *c*, age *a*, educational attainment *e*, industry *i* by: E_{scaeit}.

Table A2. Classification of labor force for each industry

	No.	Categories
Gender	2	Male; Female
Class	2	Employees; Self-employed and unpaid
Age	7	16-17; 18-24; 25-34; 35-44; 45-54; 55-64; 65+
Education		
1977-92	6	0-8 years grade school
		1-3 years High School
		4 years High School
		1-3 years College
		4 years College
		5+ years College
1992+	6	0-8 years grade school
		grade 9-12 no diploma
		High School graduate
		some College no Bachelors degree
		Bachelors degree
		more than BA degree

A.1.2 Population Census and Current Population Survey [2003-2010]

The US Census Bureau and the US Bureau of Labor Statistics produce and make available the monthly Current Population Survey (CPS). The March Supplement contains additional information on the workers and we use that to identity the labor force characteristics of that year. That is, we do not use the data from each month to compute the labor matrices. We use the answers to the questions; "During 2010 in how many weeks did you work even for a few hours include paid vacation and sick leave as work?", "In the weeks that you worked how many hours did you usually work per week?", "How much did you earn from this employer before deductions in 2010?" and "Other wage and salary earnings?"; to compute the employment, hours worked and compensation matrices by for each of the DJA98 NAICS industries in Table A1.

The CPS has a sample size of about 57,000 households containing approximately 112,000 persons 15 years and older in this period. As explained in JHS (2005) we do not use this small sample to populate the E_{scaejt} matrix which is of dimension (2,2,8,6,98) but construct smaller marginal matrices. For example, for employment we make a matrix with 98 industries and 2 classes, denoted EMP_IC(98,2). Other marginal matrices collected for employment, hours, weeks and compensation are with dimensions: EMP_IE(20,6), EMP_SCAE(2,2,8,6), HRS_ICAS(11,2,8,2), WKS_ICAS(11,2,8,2), CMP_IE(20,6) and CMP_AES(8,6,2).

The CPS converted from the SIC to the NAICS basis in 2002 and identifies 236 industries in its classification. There is a direct link between these 236 industries and the industry groups in EMP_IC(98,2) and EMP_IE(12,6), except for military workers.

The decennial Census gives a 1% sample with about 1.5 million workers in 2000 and that is used to construct the full (2,2,7,6,98) matrices for employment, hours, weeks and compensation following the same procedure as described above for the CPS (see JHS 2005). The marginal matrices from the CPS listed above are used to extrapolate these 2000 benchmark matrices to 2010. The marginal matrices from the CPS for 1991-1999 are used to interpolate the 1990 and 2000 Censuses as described in JHS (2005).

A.1.2.1 Scaling to the National Accounts

The employment, hours, weeks and compensation matrices derived from the household surveys above are denoted by EH_{scaejt}, HH_{scaejt}, WH_{scaejt} and CH_{scaejt}. We next scale them to the

NIPA released in August 2011[1]. NIPA Table 6.4 gives the number of employees for 71 industries ($E^{NIPA}_{c=1,J,t}$), T6.8 gives "persons engaged" and T6.5 gives "full time equivalent employees". The number of class 2 workers (self employed and unpaid) is given by subtracting full time equivalents from "person engaged" ($E^{NIPA}_{c=2,J,t}$),. We adjust the EH_{scaejt} matrix such that:

(A.6) $$E_{scaejt} = scale \times EH_{scaejt}$$

$$\sum_{j\in J}\sum_{sae} E_{saejt,c=1} = E^{NIPA}_{c=1,J,t}; \qquad \sum_{j\in J}\sum_{sae} E_{saejt,c=2} = E^{NIPA}_{c=2,J,t}$$

The annual hours worked in given in Table 6.9 for 18 industry groups. We sum over industries in our 98-sector system that correspond to each of these groups and scale HH_{scaejt} such that the weekly hours matrix H_{scaejt} , normalized to a 52-week work year satisfies:

(A.7) $$\sum_{j\in J}\sum_{scae} E_{scaejt} H_{scaejt} 52 = H^{NIPA}_{J,t} \qquad H_{scaejt} = scale \times HH_{scaejt}$$

A.1.3 Converting SIC labor matrices [DJA88, 1960-2002]

For all years prior to 2003 household survey data is only available on a SIC basis. The BLS program for Current Employment Statistics (CES) has produced a set of ratios to bridge the employment data from 2, 3 and 4-digit SIC series to NAICS using data from the 2001 Quarterly Census of Employment (available at http://www.bls.gov/ces/cesratiosemp.htm). We took the SIC based matrices for employment, hours, weeks and compensation for 1960 to 2002 used in Jorgenson, Ho, Samuels and Stiroh (2007) and JHS (2005), and converted them to a NAICS based set using this CES bridge.

That SIC data set covering 88 industries is referred to as the DJA88 classification, and is similarly categorized by two sexes, two classes of workers, 8 age groups and 6 education levels. Each of the DJA88 SIC industries is assigned a 2 or 3-digit SIC code. The CES bridge then allows us to allocate each of the DJA88 industry into multiple 3 or 4-digit NAICS industries. Each of these 3 or 4-digit NAICS codes are then assigned to one of the DJA98-NAICS industries. For each DJA98 industry we aggregate the ratios and thus obtain a complete bridge matrix between DJA88 SIC and DJA98 NAICS. This link is then applied to all the DJA88 SIC labor matrices for employment, hours,

[1] The NIPA is available at http://www.bea.gov//national/nipaweb/DownSS2.asp.

weeks and compensation, resulting in a NAICS-based set matrices in the DJA98 classification, cross classified by two sexes, two classes of workers, 8 age groups and 6 education levels, covering the years 1960 through 2002. Denote them by E^{Naics}_{scaejt}, H^{Naics}_{scaejt}, W^{Naics}_{scaejt} and C^{Naics}_{scaejt}.

We note that the CPS changed its educational attainment categories in 1992 from "years of schooling" to "highest grade completed". In JHS (2005) we described how we bridged these two sets of educational classifications.

A.1.4 Converting SIC labor matrices [DJA67, 1947-60]

Jorgenson, Gallop and Fraumeni (1989) (JGF) estimates labor matrices on a SIC basis for 67 industries, two sexes, two classes of workers, 8 age groups and 5 education levels for 1947-79. (The tables in JGF report estimates for 51 industries but the underlying labor data is constructed for 67 industries corresponding to those in the NIPA at that time.) We refer to this as the DJA67 dataset. The labor data in JGF are estimated using published Census tables and special labor force reports, not the micro data from the CPS used in JHS (2005) that were not available at that time.

We first revise the matrices for 1947-1960 from JGF by using the micro data in the 1950 Census (*Census of Population, 1950: Public Use Microdata Sample Technical Documentation*[2]). That is, we first constructed the employment matrix $E_{scaei}(2,2,8,5,67)$ for 1950 using the 3.33% sample with information on 461,130 "sample line persons" using the same procedure as described in JHS (2005 Chap 6). The 1950 Census identifies 149 SIC industries which we allocate to the DJA67 industries.

In Jorgenson, Ho, Samuels and Stiroh (2007) we had constructed benchmark matrices based on the 1960, 1970, 1980 and 1990 Censuses. We use this 1960 employment matrix and the 1950 benchmark just described, to interpolate the employment matrices for the years 1950-1960 using as annual control totals the data from JGF. That is, we take the employment matrices from JGF and compute the total employment by sex, by class, by age and by education for 1950-60, and scale the re-interpolated matrices to these marginal totals. The employment matrices for 1947 to 1949 are

[2] ICPSR (1984) provides an online data and documentation archive. Inter-university Consortium for Political and Social Research document ICPSR Study No. 8251, Ann Arbor, Michigan. http://www.icpsr.umich.edu/icpsrweb/ICPSR/studies/8251.

extrapolated backwards from the 1950 benchmark with growth rates from the original DJA67 matrices. We kept the hours and compensation matrices from JGF.

With this set of revised employment matrices for the DJA67 industries, we utilize two links to build a new set of DJA98 NAICS-based labor matrices for 1947-1959. In the first step the DJA67 industries are disaggregated to DJA88 SIC based industries used in JHSS (2007). The second step bridges the DJA88 SIC industries to the DJA98 NAICS industries using the CES SIC-NAICS ratios referred to above. The result is a NAICS-based labor matrix defined by DJA98 industries and categories; 98 NAICS industries, two sexes, two classes of workers, 8 age groups and 5 education levels. These matrices have 15,680 cells and cover the years 1947 through 1960.

In JHSS (2007) we were able to construct the data for 6 educational groups where the 6th group is "5 or more years college". This category was, however, not identified in the 1950 Census and we had to assume that there was no change in the allocation of the "4+ years college" group into "4 years college" and "5+ years college" during 1947-60.

A.1.5 Linking the CPS SIC in 2002 with NAICS in 2003

The CPS changed over to using NAICS beginning with the 2003 Surveys. We found that applying the CES bridge that we constructed for 2-3 digit codes to the 2002 SIC based matrices resulted in implausible jumps in the employment series. In order to create a better link between the 2002 SIC based CPS to the 2003 CPS, we first re-read the 2002 CPS March Supplement to construct a more accurate NAICS version than that made in A.1.3 above. For each worker in the 2002 Survey we link his/her industry to NAICS industries using the CES SIC-NAICS ratios. That is, a share of this particular type of worker is allocated to one NAICS industry and another share to another NAICS industry, and so on, as defined by the bridge. The information of this worker for hours, weeks and compensation are then used to construct the corresponding marginal matrices for the detailed set of NAICS codes. This detailed list of industries is then aggregated to 12 industry groups for the EMP_EI_NAICS(6 educ, 12 indus, 2002) marginal matrix. The dimensions of the other marginal matrices (e.g. EMP_SCAE) are those used for processing the 2003-2010 CPS as discussed in section A.1.2. We needed to reduce the EI matrix to 12 industry groups since the original 20 groups turned out to be too refined.

We re-read the 2003 CPS to create an EMP_EI(6 educ, 12 indus) marginal matrix with the same dimensions, but in NAICS. We then used the 2000 Population Census benchmark which is

based on NAICS, as an initial guess and created a new set of full-dimensioned 2003 matrices based on these smaller marginal matrices -- $E^{N\,2003}_{scaej}$, $H^{N\,2003}_{scaej}$, $W^{N\,2003}_{scaej}$ and $C^{N\,2003}_{scaej}$. Starting from these 2003 matrices as an initial guess, we constructed a set of 2002 matrices by the RAS procedure using the EMP_EI_NAICS(6,12,2002) marginals. We thus have a new set of full-dimensioned 2002 matrices, denoted $E^{N\,2002}_{scaej}$, $H^{N\,2002}_{scaej}$, $W^{N\,2002}_{scaej}$ and $C^{N\,2002}_{scaej}$. The growth rate of labor input between 2002 and 2003 is then computed using these $E^{N\,2002}_{scaej}$, $H^{N\,2002}_{scaej}$ and $E^{N\,2003}_{scaej}$, $H^{N\,2003}_{scaej}$ etc. matrices.

A.1.6 Linking NAICS series [1947-2010]

To summarize what we have so far; we created four distinct sets of DJA98-Naics labor matrices; for 2003-2010, 2002-03, 1960-2002, and 1947-1960. The 1960-2002 set is further divided into 1960-92 and 1992-2002 to bridge the change in educational classification. This complicated structure with multiple versions for the bridge years is needed to deal with the changes in classifications. The final step is to combine the four data sets creating a consistent time series of labor matrices from 1947 to 2010.

The growth of labor input for 2003-10 is computed by applying equation A.1 to the E^{Naics}_{scaejt}, H^{Naics}_{scaejt}, etc matrices from section A.1.2. The growth rate of labor input across the changeover years 2002/03 is just described in sectionA.1.5. The labor indices for 1960-2002 is computed from the bridged matrices from A.1.3; all having 6 educational groups. For 1947-1960, the indices are computed from the matrices in A.1.4 covering only 5 educational groups.

A.1.7 Results

We briefly summarize the main results in Table A3 and Figures A1-A3. Over the entire post War period, 1947-2010, while GDP growth was 3.2% per year, hours worked grew at 1.01%. Labor input grew much faster at 1.45%, meaning that aggregate labor quality was rising at 0.43% per year. The time series of labor input, quality and hours are plotted in Figure A1. The growth of labor quality was high in the immediate post War period, 0.44% during 1947-1973, but fell to 0.40% during 1973-95 with the rapid rise of female labor force participation; they have lower average wages compared to men. Labor quality growth was quite high during 1995-2010 when many workers in the lower education groups were laid off during the Great Recession.

The labor quality index is plotted in Figure A2 together with the partial labor input indices for sex, age and education. The steady decline in the index for sex reflects the rise of the share of female workers with their lower wages, as noted. The rapid rise in educational attainment during 1947-80 is quite clear, followed by a steady deceleration of this improvement until 2000 when the period of slow growth started and the Great Recession led to many layoffs of less skilled workers. The index for age fell between 1947 and 1980 with the entry of the baby boom generation into the work force – young workers have lower wages than the prime-age workers. After 1980 the age effect reverses as the work force started to age with the baby boomers moving into the prime-age groups.

Table A3 - Aggregate labor input, employment and hours

	1947-2010	1947-1973	1973-1995	1995-2010
GDP	3.17%	3.92%	2.79%	2.42%
Aggregate labor				
Labor input	1.45%	1.55%	1.72%	0.89%
Labor quality	0.43%	0.44%	0.40%	0.47%
Hours	1.01%	1.11%	1.31%	0.41%
First order aggregate labor quality indices				
Q^s	-0.11%	-0.10%	-0.15%	-0.06%
Q^a	0.09%	-0.04%	0.17%	0.21%
Q^e	0.40%	0.37%	0.40%	0.43%
Private sector labor				
Labor input	1.41%	1.26%	1.92%	0.93%
Labor quality	0.46%	0.46%	0.42%	0.54%
Hours	0.95%	0.80%	1.50%	0.39%
Note: All figures are average annual growth rates.				

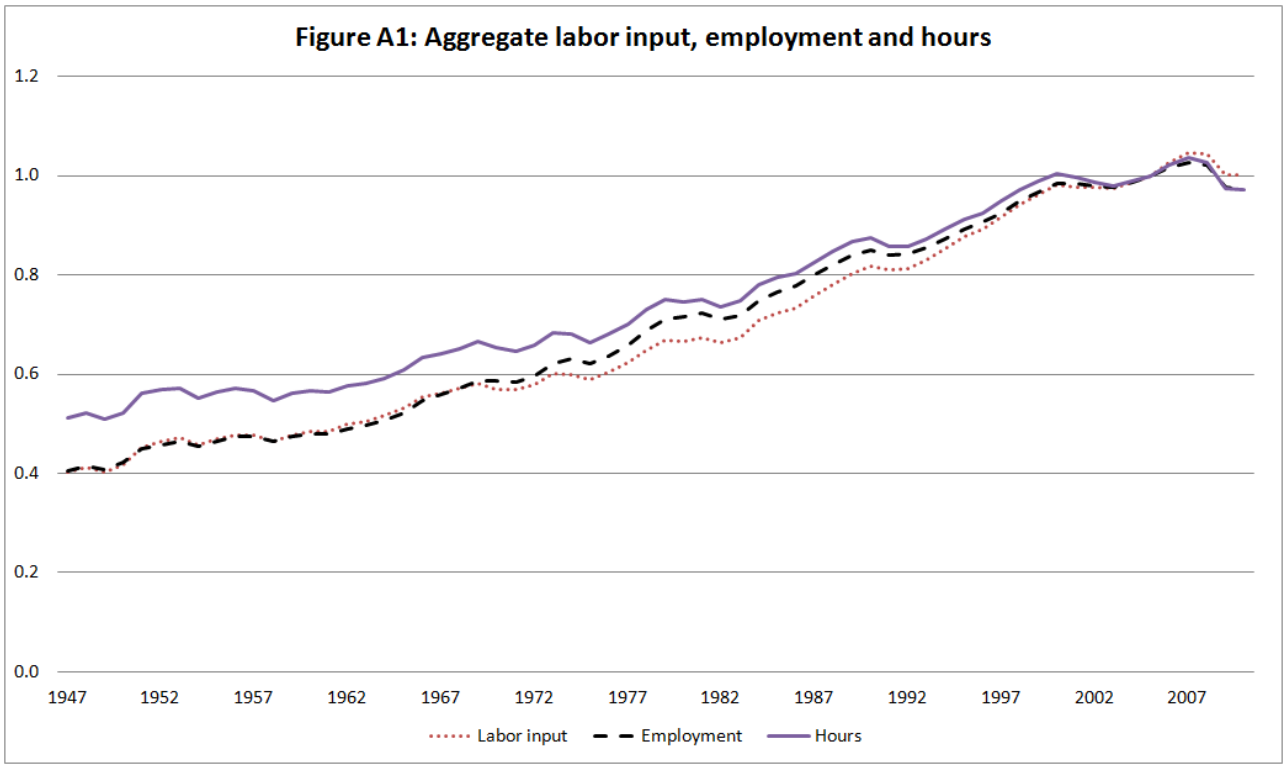
Figure A1: Aggregate labor input, employment and hours
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
Labor input
Employment
Hours

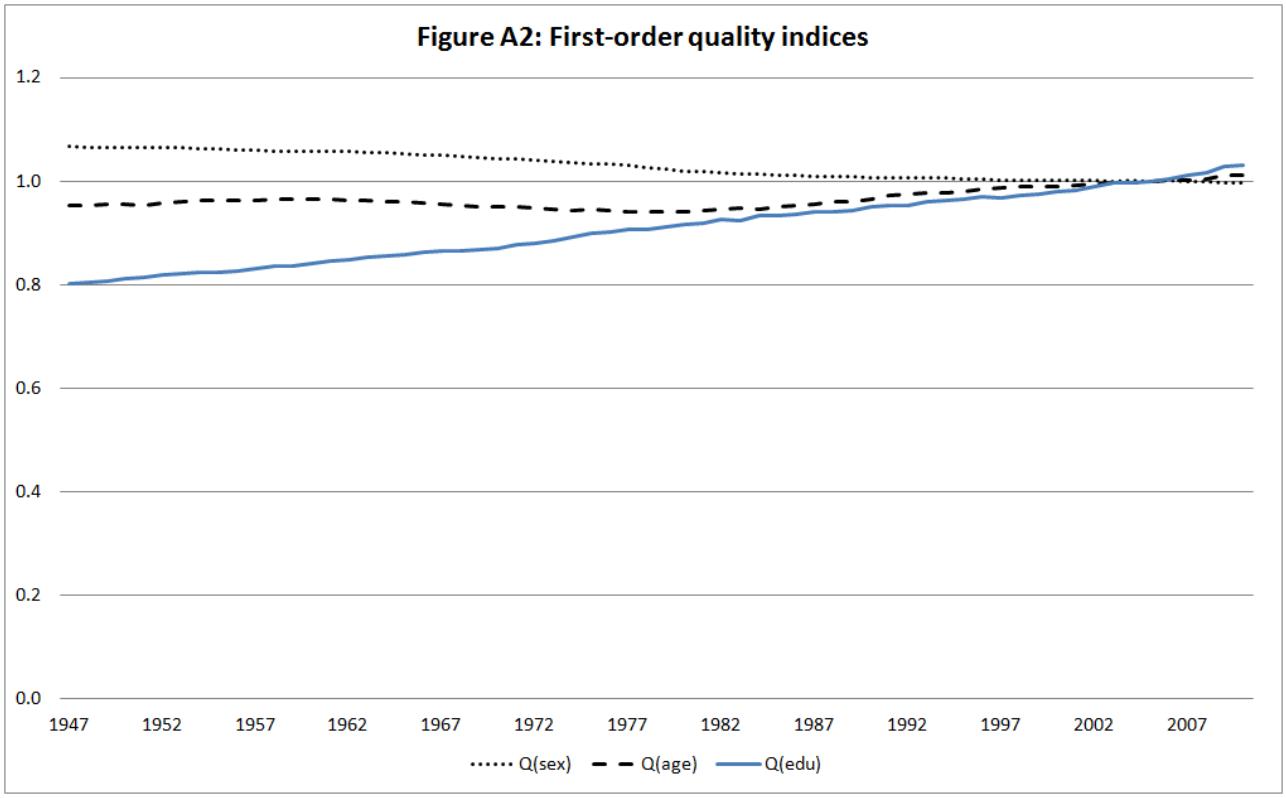
Figure A2: First-order quality indices
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1947
1952
1957
1962
1967
1972
1977
1982
1987
1992
1997
2002
2007
Q(sex)
Q(age)
Q(edu)

A.2 Capital input by NAICS industries

A.2.1 Methodology

Our methodology for constructing capital input at the industry level is described in Jorgenson, Ho and Stiroh (Chapter 5, 2005). That chapter expanded the accounts for 51 industries for 1947-1979 given in Jorgenson, Gollop and Fraumeni (1987) by including IT assets (hardware and software), and reports the capital indices for 44 SIC industries for the period 1977-2000. In Jorgenson, Ho and Samuels (2011) we used the BEA's *Fixed Asset Accounts* in NAICS to estimate capital input for 70 industries, 1960-2007. In this section we first summarize the capital index formulas and then describe the construction of data in NAICS for 1948-2010.

A key assumption for our calculation of capital input is that the "constant-quality price" indices for investment goods reflect changes in the productive characteristics of the assets over time, that is, different vintages are in "constant-quality efficiency units" that are perfect substitutes. Thus, the quantity of investment of asset *k* in industry *j* at time *t* is the nominal value divided by the price index: $I_{kjt} = VI_{kjt} / P^I_{kjt}$. Under the perpetual inventory method, with the geometric rate of depreciation δ_k, the stock of effective assets at the end of period *t* is:

$$(A.8) \quad A_{kjt} = A_{kj,t-1}(1-\delta_k) + I_{kjt} = \sum_{\tau=0}^{\infty}(1-\delta_k)^{\tau} I_{kj,t-\tau}$$

We assume that the capital service flow from asset *k* (K_{kjt}) is proportional to the average of the current and lagged stock:

$$(A.9) \quad K_{kjt} = Q^K_{kjt}\,\tfrac{1}{2}\left(A_{kjt} + A_{kj,t-1}\right) = Q^K_{kjt} Z_{kjt}$$

The constant of proportionality (Q^K_{kjt}) is the quality of asset k. The rental price of an asset employed in industry *j* is given by the cost of capital formula and takes into account the corporate income tax, depreciation allowances and other tax laws; this formula may be simplified as:

$$(A.10) \quad P^K_{kjt} = \frac{1 - ITC_{k,t} - \tau_t Z_{k,t}}{1-\tau_t}\left[r_{kjt} P^I_{kj,t-1} + \delta_k P^I_{kjt}\right] + \tau_p P^I_{kj,t-1}$$

where $ITC_{k,t}$ is the investment tax credit, τ_t is the statutory tax rate, $z_{k,t}$ is the present value of capital consumption allowances for tax purposes, τ_p is a property tax rate[3]. The asset specific rate of return, r_{kjt}, depends on the industry rate of return, the division between debt and equity and the various taxes on income and capital gains. Versions of (A.10) that take into account tax structure by legal form are used for noncorporate and household capital.

Aggregating over asset types, and substituting in (A.9), the total annual capital input growth for industry *j* is a weighted average of the growth of the quantity of capital services:

(A.11) $$\Delta \ln K_j = \sum_k \overline{v}_{kj} \Delta \ln K_{kj} = \sum_k \overline{v}_{kj} \Delta \ln Z_{kj}$$

where the value share weights are:

(A.12) $$v_{kj} = \frac{P_{kj}^K K_{kj}}{\sum_k P_{kj}^K K_{kj}}; \qquad \overline{v}_{kjt} = \tfrac{1}{2}\left(v_{kjt} + v_{kjt-1}\right)$$

The quantity of capital stock for *j* is similarly defined using the asset price as weights: $\Delta \ln Z_j = \sum_k \overline{w}_{k,j} \Delta \ln Z_{kj}$, $w_{kj} = P_{kj}^I Z_{kj} / \sum_k P_{kj}^I Z_{kj}$. The quality of capital for industry j is defined as the ratio of service flow to the stock:

(A.13) $$Q_{jt}^K = \frac{K_{jt}}{Z_{jt}}$$

In order to focus on IT capital we also calculate (A.11) for the IT and non-IT sub-aggregates of total industry capital: $\Delta \ln K_{jt}^{IT} = \sum_{k \in IT} \overline{v}_{kj}^{IT} \Delta \ln K_{kj}$ and $\Delta \ln K_{jt}^{NON} = \sum_{k \notin IT} \overline{v}_{kjt}^{NON} \Delta \ln K_{kj}$. The list of fixed assets is given in Table A4 together with their depreciation rates, the first three are in the IT group. Our capital accounts also include estimates of land and inventories, consumer durables and government assets.

[3] The full discussion of our cost of capital formulas is in Jorgenson and Yun (2001).

Table A4. Asset types, investment (2005) and depreciation rates

	Asset	Depre. rate	Investment (bil $)
Information Technology			377.8
1	Computers and peripheral equipment	0.3119	76.6
2	Software	0.3974	218
3	Communication equipment	0.1100	83.2
Non-IT equipment			599.4
4	Medical equipment and instruments	0.1350	58.6
5	Nonmedical instruments	0.1350	23.6
6	Photocopy and related equipment	0.1800	4.5
7	Office and accounting equipment	0.3118	8.6
8	Fabricated metal products	0.0917	13.5
9	Engines and turbines	0.0723	5.5
10	Metalworking machinery	0.1225	26.3
11	Special industry machinery, n.e.c.	0.1032	31.4
12	General industrial equipment	0.1072	57.6
13	Electrical trans, distrib, industrial apparatus	0.0500	22.3
14	Light trucks (including utility vehicles)	0.1925	62.5
15	Other trucks, buses, and truck trailers	0.1917	36.2
16	Autos	0.2719	36.5
17	Aircraft	0.0825	20.8
18	Ships and boats	0.0611	4.7
19	Railroad equipment	0.0589	6.9
20	Furniture and fixtures	0.1179	42.4
21	Agricultural machinery	0.1179	21.6
22	Construction machinery	0.1550	31.5
23	Mining and oilfield machinery	0.1550	7.4
24	Service industry machinery	0.1550	21.9
25	Electrical equipment, n.e.c.	0.1834	6.3
26	Other nonresidential equipment	0.1473	48.8
Private non-residential structures			351.9
27	Office buildings	0.0247	42.6
28	Religious buildings	0.0188	7.7
29	Educational and vocational buildings	0.0188	13.8
30	Medical buildings	0.0247	9
31	Multimerchandise shopping	0.0262	22.8
32	Food and beverage establishments	0.0262	7.8
33	Commercial warehouses	0.0222	12.8
34	Other commercial buildings, n.e.c.	0.0262	17.4
35	Manufacturing	0.0314	29.7
36	Electric	0.0211	21.6
37	Other power structures	0.0237	7.1
38	Petroleum and natural gas	0.0237	73.5
39	Communications	0.0237	18.8
40	Mining structures	0.0751	3.5
41	Hospital and institutional buildings	0.0188	20.5
42	Special care	0.0188	2.5
43	Lodging	0.0281	15.7
44	Amusement and recreational buildings	0.0300	9
45	Transit buildings; air	0.0237	0.9
46	Transit buildings; land	0.0237	6.2
47	Farm buildings	0.0239	5.9
48	Other structures	0.0250	3.1
Residential structures			765.1
49	1-to-4-unit	0.0114	544.7
50	5-or-more-unit	0.0140	44.4
51	Mobile homes	0.0455	10.1
52	RS; Improvements	0.0255	164.4
53	Other residential structures	0.0227	1.5

A.2.2 Investment and stock data by industry

The Fixed Asset accounts of the BEA include estimates of investment by detailed asset types by industry going back to 1901. For non-residential fixed assets, this covers 63 industries and 74 assets which we collapse to our 61 private economy industries and the asset classification given in Table A4. We assign residential assets in the Fixed Asset account of the BEA to the Residential structures categories in Table A4 and assume that all of these assets belong to the Real Estate industry. The non-residential and residential fixed asset data includes the nominal (historical cost) values and the investment price index as described above[4]. The depreciation rates in Table A4 are taken from *BEA Depreciation Estimates*.[5] For the national private economy, total investment in 2005 (before the Great Recession) was $2104 billion, of that; 378 billion went to IT equipment and software, 599 to non-IT equipment and 1117 to structures.

The starting point for the capital services estimates for the Household and Government sectors is also the Fixed Asset accounts of the BEA. The residential fixed asset data contains nominal and real investment in six types of owner occupied housing and the NIPA contains estimates of the implicit rent from this stock. We use the implicit rent in the NIPA as a control total to compute a rate of return to housing assets, and use this rate of return to calculate the implicit price of capital services for each type of owner occupied capital. Finally, we use the average rate of return in the private economy to impute a service flow the government capital assets which are also contained in the Fixed Asset accounts.[6]

Our definition of capital input includes land and inventories. The national Change in Business Inventories (for farm and non-farm CBI), in nominal and deflated terms, are given in the NIPA. Inventory stocks by industry are given in NIPA table 5.7.6 and additional industry detail is given in the underlying detail tables 1BU. In cases where our level of classification is finer than that published,

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[4] The data is available at the BEA web page http://www.bea.gov/iTable/index_FA.cfm. The BEA methodology is described in BEA (2003).

[5] Downloaded from http://www.bea.gov/national/FA2004/Tablecandtext.pdf November 2010. Note that because the asset detail in the Fixed Asset accounts is finer than that in Table A4, in some cases we approximate the depreciation rate as a weighted average of that used by the BEA. For autos, our estimates use the best geometric approximation to the BEA rate. Although BEA allows some assets to have industry-specific depreciation rates, we impose equal rates across industries.

[6] Depreciation rates for government assets are also taken from the report: BEA Depreciation Estimates.

we allocate using industry income shares. We extrapolate inventory stocks back to 1947 using SIC-based industry stocks that were constructed for JHS(2005). The stock of inventories is assumed to have a depreciation rate of zero.

Estimates of land are sparse. The control total for the total land stock is based on data in the Flow of Funds accounts. The nominal value of household land is estimated as the difference between the market value of real estate and the market value of structures given in the FoF. Historical ratios from Jorgenson (1990) are applied to this control total to estimate total corporate and noncorporate land. Finally, these are allocated by industry using the SIC-based industries in JHS(2005). The price of land is assumed to be the same across industries. For agricultural land we use the stock estimates from the Department of Agriculture Economic Research Service productivity accounts[7]. We should note that while the land estimate is poor, the total quantity does not vary much over time. There is some reallocation between industries; the major impact of including it is to slow the growth of capital input.

The dominant feature of investment in the Information Age is the fall in the relative prices of investment goods, in particular the price of information technology investment. The prices between 1960 and 2010 for the major asset types are plotted in Figure A3, all given relative to the GDP deflator, in log scale. The price of private fixed investment as a whole fell at an average of 0.75% per year during this period while the price of computers and peripheral equipment fell at 21%! Communications equipment fell at 3.2% and transportation equipment at 0.83% per year. More than half of annual private investment is in structures, and, in contrast to the equipment prices, the price of non-residential structures rose by 1.1% per year.

[7] The land data for agriculture is kindly provided by Eldon Ball of the Economic Research Service (Ball, Schimmelpfennig and Wang (2013). See also the web page http://www.ers.usda.gov/data-products/agricultural-productivity-in-the-us.aspx.

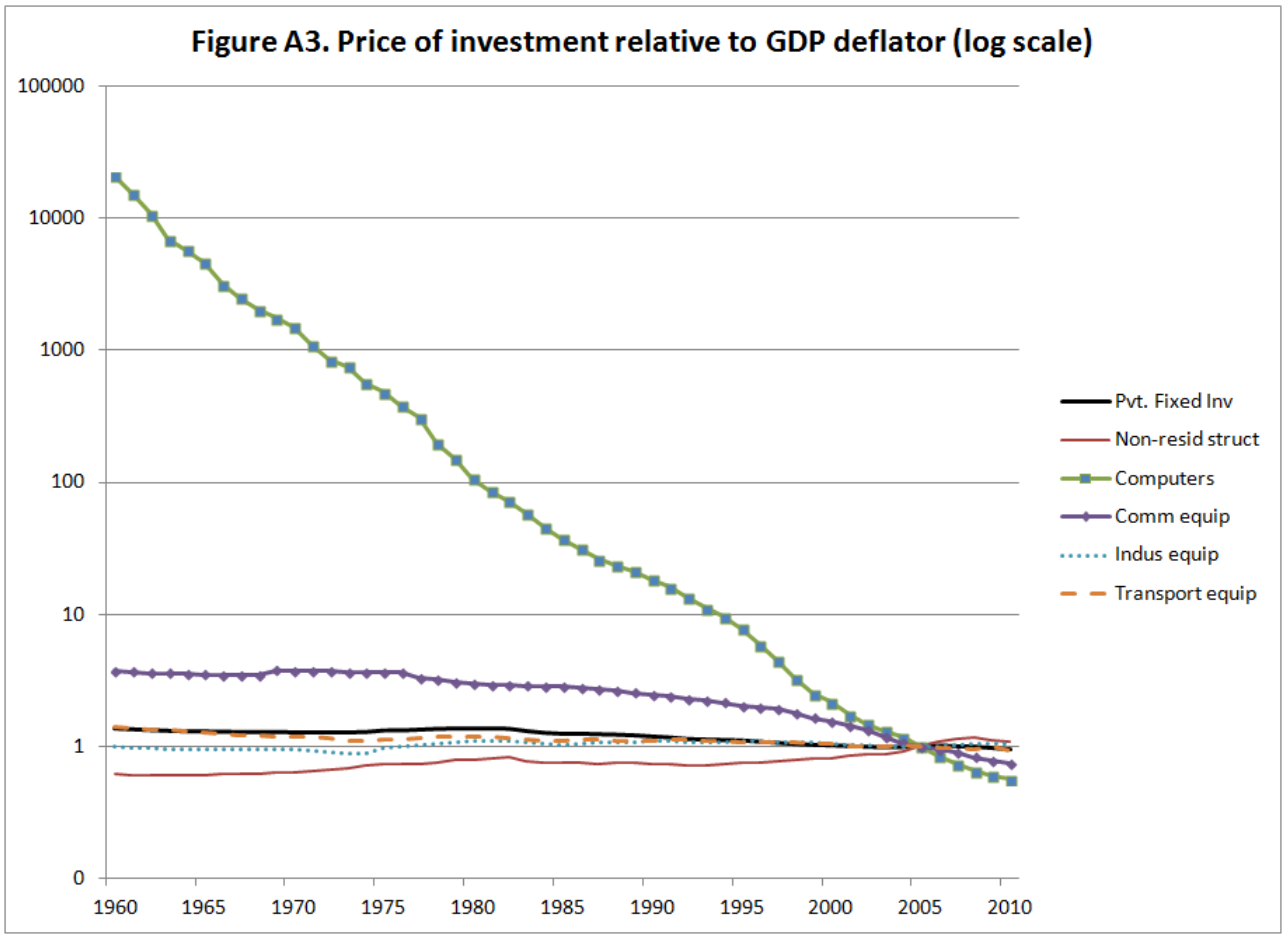
Figure A3. Price of investment relative to GDP deflator (log scale)
100000
10000
1000
100
10
1
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Pvt. Fixed Inv
Non-resid struct
Computers
Comm equip
Indus equip
Transport equip

A.2.3 Value added and value of capital input

The BEA's GDP by Industry accounts give the value added for the 65 industries in the NIPA for 1998 onwards. The construction of nominal value added (VA) for our more disaggregated list of industries in Table A1, and going back to 1947, is described in the input-output section A.3.1 below (in step 4.2.2). The value of labor input (for both employees and self employed and unpaid family workers) is described in section A.1.2 above, and the value of capital input is total industry VA less labor value. That is, we assume that self-employed workers by demographic group are paid the same rate as employees and the residual income is allocated to capital.

Next we allocate this industry capital value added to the corporate and non-corporate components given the different tax treatments for these two forms of organization. The share of capital stock going to the corporate sector uses the older BEA investment data that distinguishes corporate and non-corporate investment (JHS 2005, Chapter 5). We use these old ratios to allocate the latest version of the BEA's *Fixed Asset Accounts* that do not provide such a distinction

Given this estimate of value of corporate capital input for each industry, the denominator of (A.12), we may calculate the industry rate of return for the corporate sector. With that, we calculate the cost of capital for each asset type (P_{kj}^{K}). This is repeated for the non-corporate and household sectors.

A2.4 Results

We begin by reporting the share of IT capital input in total capital ($P_{ITjt}^{K} K_{jt}^{IT} / P_{jt}^{K} K_{jt}$) in Table A5 for the year 2005, i.e. two years before the Great Recession. At the low end are the sectors where land is dominant; the IT share is only 0.2% in Farms, 0.39% in Real Estate, and 1.6% in Oil and gas extraction. At the other end, the share is about 90% for the two IT services – Computer systems design and Information and data processing -- and above 70% for Management of companies, Securities and commodity contracts, and Publishing (including software). Other large significant users of IT are Air transportation (31.3%), Wholesale trade (20.3%) and Federal Reserve Banks and credit intermediation (20.6%).

Next we turn to the growth of capital input, Table A6 gives the growth rates of total capital input, IT capital and capital quality for each industry. We report the average annual growth rates for the entire Post-War (1947-2010) as well as the 1973-95 and 1995-2010 sub-periods.

Table A5. IT capital intensity in 2005 (share of IT capital in total capital)

Farms	0.0020	Pipeline transportation	0.2137
Forestry, fishing	0.0311	Other transportation	0.1099
Oil and gas extraction	0.0163	Warehousing and storage	0.0623
Mining, except oil and gas	0.0202	Publishing industries	0.7244
Support activities for mining	0.0667	Motion picture and sound	0.2509
Utilities	0.0529	Broadcasting and telecom	0.6105
Construction	0.0865	Information and data processing	0.8878
Wood products	0.0506	Fed res banks; credit interm.	0.2061
Nonmetallic mineral products	0.0459	Securities, commodity ctrct	0.7557
Primary metals	0.0272	Insurance carriers	0.3999
Fabricated metal products	0.0645	Funds, trusts & other financial	0.0343
Machinery	0.1637	Real estate	0.0039
Computer and electronic	0.3203	Rental & leasing; lessors	0.1206
Electrical equip, appliances	0.1124	Legal services	0.3216
Motor vehicles, bodies & parts	0.0775	Computer systems design	0.9094
Other transportation equipment	0.1750	Misc. professional, scientific svcs	0.4700
Furniture and related products	0.0743	Management of companies	0.7677
Miscellaneous manufacturing	0.1234	Administrative services	0.5874
Food, beverage & tobacco	0.0599	Waste management	0.0463
Textile mills	0.0566	Educational services	0.2338
Apparel, leather and allied prod.	0.0801	Ambulatory health care services	0.1027
Paper products	0.0589	Hospitals, nursing & resid. care	0.1599
Printing	0.1652	Social assistance	0.1666
Petroleum and coal products	0.0391	Performing arts, spec. sports	0.1475
Chemical products	0.0936	Amusements, recreation	0.0879
Plastics and rubber products	0.0676	Accommodation	0.0337
Wholesale trade	0.2031	Food services, drinking places	0.0313
Retail trade	0.1145	Other services, except govt	0.1035
Air transportation	0.3126	Federal Gen. Government	0.0989
Rail transportation	0.0189	Federal govt enterprises	0.0989
Water transportation	0.2267	State & Local Gen. Govt	0.0989
Truck transportation	0.1171	S&L govt enterprises	0.0989
Transit & ground transp.	0.0881		

Table A6. Capital input, IT capital and Capital quality growth

	1947-2010			1973-1995			1995-2010		
	Capital input	IT capital	Capital Quality	Capital input	IT capital	Capital Quality	Capital input	IT capital	Capital Quality
Farms	0.77	13.3	0.7	1.02	35.7	1.28	0.36	3.4	0.43
Forestry, fishing	3.59	13.7	0.58	3.79	14.0	0.33	-0.07	10.6	0.24
Oil and gas extraction	3.4	14.7	0.03	3.03	18.5	-0.02	1.89	10.2	0.03
Mining, except oil and gas	1.16	13.3	-0.19	1.31	26.2	-0.64	-0.43	3.4	-0.14
Supp activities for mining	4.05	15.6	0.32	2.88	18.0	0.21	1.89	12.7	0.35
Utilities	3.34	11.2	0.37	2.78	20.8	0.63	1.9	6.6	0.48
Construction	3.89	16.3	0.38	1.51	25.4	0.34	5.63	9.1	0.98
Wood products	2.56	12.6	0.38	1.42	19.7	0.38	-0.14	6.3	0.02
Nonmetallic mineral prod.	2.55	12.3	0.72	1.92	17.2	1.23	1.24	4.9	0.34
Primary metals	1.88	11.9	0.67	0.7	13.7	0.75	-0.03	2.7	0.87
Fabricated metal products	2.98	13.4	0.35	2.77	18.9	0.6	1.16	6.2	0.27
Machinery	4.37	16.0	0.73	4.47	15.8	0.7	1.93	5.4	0.5
Computer and electronic	7.42	14.3	2.63	8.11	17.7	3.14	4.67	8.8	1.85
Electrical equip, appliances	3.77	7.2	0.27	4.33	12.8	0.34	0.15	5.2	0.25
Motor vehicles, parts	3.9	20.2	0.97	3.01	18.5	1.04	2.69	2.3	0.55
Other transportation equip	3.74	14.1	0.56	4.06	20.2	1.17	1.82	6.2	0.57
Furniture and products	3.11	14.0	0.38	3.19	23.1	0.49	2.16	10.9	0.85
Miscellaneous manuf.	4.12	22.4	0.99	2.8	21.1	0.48	2.38	10.2	0.52
Food, beverage & tobacco	2.08	16.2	0.27	2.64	17.2	0.31	1.04	8.5	0.29
Textile mills	0.92	12.7	0.51	0.92	14.3	0.42	-2.54	5.2	-0.13
Apparel, leather	1.89	12.8	0.07	1.93	17.5	-0.04	-1.61	5.9	0.22
Paper products	2.58	14.8	0.23	3.22	17.2	0.4	-1.23	4.5	0.04
Printing	3.39	20.7	0.87	3.99	25.2	1.34	1.76	11.0	1.27
Petroleum and coal products	3.9	13.3	1.01	2.73	14.3	0.74	2.33	11.5	0.56
Chemical products	3.87	16.0	0.41	4.01	23.2	0.61	1.81	7.8	0.5
Plastics and rubber products	3.94	15.3	0.16	3.03	17.0	0.09	1.55	12.3	0.3
Wholesale trade	6.29	21.8	1.72	5.93	26.6	1.37	3.67	10.4	1.03
Retail trade	4.86	25.5	1.52	5.01	30.1	1.78	3.91	12.4	1.34
Air transportation	5.93	12.0	0.67	3.64	16.5	0.71	2.26	5.0	-0.21
Rail transportation	-0.47	5.0	0.2	-0.47	11.9	0.36	0.34	2.6	0.37
Water transportation	0.81	13.3	0.2	2.54	23.2	1.5	0.17	1.4	-0.31
Truck transportation	3.19	16.8	0.5	0.63	28.0	0.92	3.47	15.5	0.15
Transit & ground transp.	-0.28	2.6	0.46	0.32	6.5	0.3	2.01	1.8	1.13
Pipeline transportation	3.56	18.9	1.79	4.58	19.9	2.69	5.98	3.1	2.39
Other transportation	0.98	12.7	0.61	1.88	20.5	1.77	0.72	10.3	0.73
Warehousing and storage	2.69	17.5	1.03	2.62	36.6	2.52	3.58	12.3	0.59
Publishing industries	7.56	18.0	2.83	8.08	20.9	3.87	10.6	17.3	4.83

Motion picture and sound	3.51	11.9	-1.06	3.91	27.2	-1.64	1.34	8.9	-0.21
Broadcasting and telecom	6.41	8.6	1.02	5.35	6.1	0.63	5.51	8.0	1.46
Information, data process.	11.36	16.9	0.78	9.64	21.2	1.4	18.1	22.5	2.45
Fed res banks; credit interm.	7.33	20.8	1.17	9.33	28.0	1.42	5.3	11.7	1.67
Securities, commodity ctrct	14.13	18.7	2.98	16.59	18.4	1.66	12.15	15.2	7.02
Insurance carriers	9.81	15.4	1.08	11.35	16.4	1.28	4.39	12.3	1.44
Funds, trusts & other finan.	10.48	18.4	2.68	6.57	9.4	0.56	7.06	14.2	0.78
Real estate	2.46	7.3	0.15	2.17	4.3	0.12	1.45	12.5	0.05
Rental & leasing; lessors	8.42	17.7	0.59	6.42	26.1	1.42	8.36	11.8	0.49
Legal services	6	16.5	-0.06	5.7	14.0	0.01	6.53	19.1	0.74
Computer systems design	10.59	18.6	1.93	12.68	20.5	2.62	14.42	16.0	4.2
Misc. prof., scientific svcs	9.76	16.1	1.83	8.07	17.2	1.17	10.36	14.1	1.75
Management of companies	9.17	16.9	5.06	8.25	17.2	3.41	9.82	15.1	8.22
Administrative services	9.34	16.8	2.28	10.01	20.9	2.18	10.58	17.4	2.95
Waste management	3.05	15.0	0.34	5.48	22.5	0.27	-0.12	0.8	0.1
Educational services	7.05	15.7	3.26	4.33	18.5	2.28	11.17	17.2	6.94
Ambulatory health care	7.85	15.5	1.52	8.53	26.5	3.28	3.62	9.5	1.07
Hospitals, nursing	6.57	12.0	1.31	6.12	18.4	2.06	5.57	9.6	1.91
Social assistance	5.41	12.6	1.4	5.48	17.1	2.08	6.53	13.7	2.25
Performing arts, spec. sports	3.96	8.6	1.14	3.23	6.8	1.51	6.1	13.4	1.2
Amusements, recreation	3.61	10.2	0.55	2.25	8.5	0.54	5.82	16.6	0.45
Accommodation	3.77	22.3	0.51	2.7	19.7	0.65	3.51	9.9	0.26
Food services, drinking	3.41	16.3	0.52	3.49	30.4	0.47	1.45	7.2	0.21
Other services, except govt	3.22	12.8	-0.05	1.74	18.7	-0.14	2.29	12.9	0.03
Federal Gen. Government	0.94	6.4	0	0.97	5.7	0	3.1	9.2	0
Federal govt enterprises	3	12.4	0	3.34	9.8	0	1.1	4.4	0
State & Local Gen. Govt	3.83	13.3	0	3.17	9.6	0	4.09	7.4	0
S&L govt enterprises	3.03	8.5	0	2.59	7.3	0	2.95	9.0	0

Note: All figures are average annual percentage change.

Aggregate capital input grew at an average rate of 3.58% per year during 1947-2010 (Table 2), but we can see a wide range of growth rates at the industry level – more than 10% per year for Securities and commodity contracts, Information and data processing, Computer systems design, and Funds, trusts and other financial vehicles, and on the other end, negative for Rail transportation and Transit and ground transportation.

During the Information Age and Great Recession (1995-2010), while aggregate capital input grew at an average of only 3.2% per year, it grew rapidly for the IT sectors with the boom in Information Technology even though these are labor intensive industries (4.7% for Computers, 18% for Information and data processing, 14% for Computer system design). Capital input also grew rapidly during this sub-period for Securities, commodity contracts, Publishing (including software) and Educational services.

While there is a wide range of growth rates for total capital input, all industries had a high rate of growth of IT capital input, as shown in Table A6. Growth was especially rapid during 1973-1995 where even Agriculture had a 36% growth rate of IT capital input and Food services had 30%. The slowest rates of growth of IT capital were in the government group, and these were not very slow either: 5.7% for Federal general government and 9.6% for State and local general government. In the 1995-2010 sub-period, IT capital growth decelerated from the fast pace in 1973-95, but they were still high; beyond the rapid growth of the IT group, Truck transportation and Publishing had growth rates exceeding 15% while the large Wholesale and Retail trade sectors both had rates exceeding 10% year.

Finally, Table A6 gives the growth of capital quality, the ratio of services to stock. A rising quality index means a shift towards assets with a higher rental cost, i.e. those with a shorter useful life. For the aggregate private stock of capital, quality was rising at 0.38% per year over the entire 1947-2010 period (Table 1). At the industry level, however, there is a wide range of changes in capital quality, from -1.1% in Motion picture and sound recording to 5.1% in Management of companies. There is a slight tendency for the industries with a higher growth of capital input to have a higher rate of growth of quality, but there are many exceptions, e.g. Air transportation grew rapidly with capital input rising at 5.9% per year on average, but quality grew at only 0.67%. During the Information Age and Great Recession (1995-2010), aggregate capital quality rose at 0.36%, but at the industry level, the quality in Management of companies, Securities and commodity contracts, and

Educational Services all grew in excess of 6% per year. Wholesale and Retail trade had capital quality growing faster than 1.0% during 1995-2010.

A.3 Intermediate input

In this section we first describe the compilation of the Use and Make (or Supply) tables in nominal terms for the period 1947-2010. Next we discuss the construction of prices to deflate output and inputs. In section A.3.3 we describe the construction of prices of imported inputs. We only give a brief summary here; the framework is the same as that explained in detail in Jorgenson, Ho and Stiroh (2005, Chapter 4).

There are many sources of data used and different levels of aggregation; we use the notation shown in Table A7 to distinguish them.

Table A7. Data sources and notation

$U_{ijt}^{BEA\_an}$	BEA Annual IO	1998+
$M_{jit}^{BEA\_an}$	U: Use table; M: Make	
$U_{ijt}^{BEA\_PL}$	BEA/Planting IO; 65 sectors	1963-97
$U_{ijt}^{BEA\_PL\_47}$	BEA/Planting IO; 46 sectors	1947-62
U_{ijt}^{BLS}	BLS (Emp Projections) IO; about 200	Various versions
$U_{ijt}^{BEA\_J65}$	BEA 65sector tables rearranged to DJA format	1947-2010
U_{ijt}^{DJA87}	IO tables in DJA87 classification	1947-2010
VQI_{ijt}^{BEA}	BEA Industry gross output, nominal value, 426 sectors	1998+
VQI_{ijt}^{BLS}, VQC_{ijt}^{BLS}	BLS Industry gross output, commodity output; about 200 sectors	Various versions
VQI_{ijt}^{DJA87}	Industry output in DJA87 classification	1947-2010

A.3.1 Nominal input-output tables

The BEA Industry Economic Accounts Directorate has been preparing "annual" input-output tables that are extrapolated from the benchmark tables regularly since the release of the 1997 benchmark in 2002. Prior to that there were only irregular extrapolations, there was no systematic, production of such annual tables. The data series covering 1998-2010 was released in December 2011. These consist of Use and Make tables for 65 sectors based on NAICS-2002; i.e. the same 65

sectors as those in the most recent version of the GDP by Industry accounts[8]. (The Income and Employment tables in the NIPA cover a similar set of industries; e.g. Table 6.17D gives Corporate Profits for these industries plus three more. See *Survey of Current Business*, August 2011). These annual inter-industry transaction tables are based on the more detailed benchmark table for 2002 that covered 426 industries, 8 of which are government sectors.

In 2011, the BEA also made available Use and Make tables based on the same 65 NAICS sectors, covering the period 1963-1997. A separate series is given for a more aggregated list of 46 industries for 1947-62. These IO tables were estimated by Mark Planting based on the 1997 Benchmark IO that was revised to be consistent with the GDP given in the 2011 Annual Revision of the NIPA.

We used the above BEA IO tables to construct the nominal value portion of our inter-industry accounts following these steps.

1. We expanded the 46-sector tables from BEA/Planting for 1947-62 to 65 sectors using historical industry output data in the SIC system. The first source of old SIC data is the BLS Office of Employment Projections which provided industry output data for 222 SIC industries for 1958-1988[9]. Jorgenson, Gollop and Fraumeni (1987) constructed accounts for 51 industries for the period 1947-79, in part using this BLS output data. The sectors in the BEA data for 1947-62 that have to be disaggregated are: Transportation, Information, Finance & Insurance, Professional, scientific & technical services, Administration & waste management, Education, health care & social services, and Arts, entertainment & recreation. For the sectors that were not available in Jorgenson, Gollop and Fraumeni (1987) we used the Compensation of Employees in the NIPA to allocate the gross output for those years; i.e. assuming that output shares are equal to compensation shares of each industry group.

In order to expand the IO tables we first constructed the value of industry output for the 65 disaggregated industries using the information in JGF and NIPA Compensation. The results are given in Table A6. Next, the MAKE matrices (1947-62) were disaggregated using the full 65-sector MAKE in 1963; we used the 1963 row shares for each industry in the MAKE matrix

[8] Both input-output tables and GDP by industry data are given at http://www.bea.gov/industry/index.htm#annual.

[9] This data is described in Wilcoxen (1988) and Jorgenson, Gollop and Fraumeni (1987).

to link industry output for the 65 industries to the commodity output for 65 commodities. With these industry and commodity output for 65 sectors we then adjusted an initial guess of the Use matrices to obtain a consistent set of 65-sector inter-industry transactions using the method of iterative proportional fitting (RAS); we start from an initial guess of the 1962 matrix based on the 1963 Use table and work backwards to 1947. Denote this adjusted BEA/Planting series as $U_{ijt}^{BEA\_PL}$ and $M_{jit}^{BEA\_PL}$, t=1947,.., 1962.

Table A6. Disaggregating BEA industry output from 42 to 65 industries, 1947-62

	1947	1948	1949	1950	1951	1952	1953	1954	1955	1956	1957	1958	1959	1960	1961	1962
Air transportation	608	745	866	949	1116	1279	1529	1510	1685	1876	2025	2164	2684	3047	3284	3907
Rail transportation	9898	10899	10230	11386	12341	12566	12684	10214	10829	11339	11046	9948	10737	10722	10437	11330
Water transportation	1995	1825	1925	1948	2594	2472	2449	2043	2232	2466	2500	1975	2184	2383	2292	2638
Truck transportation	3143	3787	4312	5594	6167	6535	7298	6423	7364	7775	8063	7924	9448	9486	9729	10896
Transit and ground passenger transp	3579	3615	3696	3735	3814	3893	3957	3477	3443	3545	3562	3377	3564	3612	3498	3684
Pipeline transportation	550	629	666	789	923	990	1042	997	1075	1172	1138	1111	1224	1247	1298	1418
Other transportation activities	3340	3131	3130	3403	4077	4451	4724	4759	5598	5960	6520	6431	6297	6253	6698	6361
Publishing industries (incl. software)	4154	4246	4709	4979	5484	5779	6089	6329	6685	7169	7528	7707	8387	8426	8350	8893
Motion picture and sound recording	2535	2472	2450	2471	2517	2593	2545	2619	2757	2749	2759	2645	2733	2598	2660	2653
Broadcasting and telecommunications	3486	4509	4916	5586	6389	7293	8365	8618	9460	10290	11432	12640	13405	14947	15636	17222
Information, data processing services	332	416	439	484	537	595	664	665	710	751	813	875	964	974	997	1096
Fed Res. banks, credit intermediation	4492	4870	5101	5650	6508	7007	8162	8800	9772	10691	11298	11488	12261	13944	15084	16260
Securities commodity contracts	762	770	740	972	1085	1047	1136	1439	1787	1813	1792	1975	2498	2644	3457	3267
Insurance carriers	5186	5742	6070	6802	7684	8143	9518	10196	10962	11817	12583	12894	13819	15237	16213	17358
Funds, trusts and other financial	537	610	604	579	646	754	813	881	980	1086	1153	1258	1396	1473	1657	1790
Legal services	1390	1530	1682	1978	2269	2511	2819	3089	3451	3725	4083	4390	4977	5297	5832	6416
Computer systems design svcs	514	570	586	635	735	806	872	912	1011	1128	1253	1283	1450	1525	1665	1832

Misc. professional scientific svcs	3480	3863	3972	4303	4979	5460	5909	6180	6851	7642	8492	8693	9823	10332	11285	12411
Management of companies	5197	5779	5778	6440	7423	7813	8341	8258	9146	9587	10076	9927	11018	11295	11569	12569
Administrative and support svcs	1106	1203	1252	1433	1690	1886	2114	2258	2559	2935	3285	3504	3959	4281	4650	5129
Waste management	941	1026	1112	1233	1398	1506	1626	1708	1809	1904	2019	2145	2230	2236	2304	2342
Educational svcs	1125	1462	1524	1598	1681	1844	1989	2218	2388	2787	3115	3454	3926	4269	4732	5401
Ambulatory health care svcs	3606	3883	3990	4230	4538	4985	5373	5836	6197	6763	7338	8114	8977	9621	10154	11045
Hospitals, nursing, residential care	2135	2406	2505	2723	2993	3372	3693	4069	4359	4808	5259	5862	6529	7023	7431	8111
Social assistance	244	290	316	329	351	381	415	451	475	524	561	609	690	749	795	865
Performing arts, spectator sports	1439	1424	1404	1374	1396	1447	1500	1577	1698	1821	1768	1787	1993	2224	2434	2673
Amusements gambling, recreation	1597	1580	1558	1524	1549	1606	1664	1750	1884	2020	1961	1983	2211	2467	2700	2966

2. We then took the BEA's annual tables for 1998-2010, $U_{ijt}^{BEA\_an}$, and made them match the format used by Planting in the 1947-1997 series. The Use tables provided by Planting have distinct rows for Noncomparable imports (NCI) and Rest-of-the-World (ROW) in the final demand section like the Benchmark input output tables, but the annual tables for 1998-2010 combined them. The ROW row in the inter-industry part of the Use table is zero and we simply allocate the entire combined value in each column to NCI for that column. For the combined cells in the final demand columns (Imports, Private Fixed Investment (PFI) and Change in Business Inventories (CBI) they are completely allocated to the NCI row. That is, we assume that the total Noncomparable Imports is given by the value in the combined cell in the Import column. Given this total NCI, we put all remaining NCI that is not accounted by the intermediate purchases, PFI and CBI to the PCE column. Given this estimate of the cell $U_{NCI,PCE,t}^{BEA\_PL}$, we allocate the remainder of combined $U_{NCI\_ROW,PCE,t}^{BEA\_an}$ cell to the ROW cell, $U_{ROW,PCE,t}^{BEA\_PL}$.

The annual $U_{ijt}^{BEA\_an}$ (1998-2010) has more Final Demand columns {Federal def. consumption; Fed def. investment; Fed nondefense cons.; Fed nondefense Inv; S&L cons. – education; S&L inv. – education; S&L con. – other; S&L inv. – other}, while the Planting-IO only identifies S&L gov. cons. and S&L gov. investment. We combined these sectors in the annual tables to match Planting's version. For the 1947-62 series, the Planting-IO further narrows them to Federal consumption and Federal Investment only. In the end we have these final demand categories in our database: i) Personal Consumption Expenditures; ii) Fixed Investment; iii) Change in Business Inventories; iv) Exports; v) Imports; vi) Federal Government Defense Consumption; vii) Fed. Govt. Def. Investment; viii) Fed. Govt. Nondefense Consumption; ix) Fed. Govt. Nondefense Investment; x) State and Local Government Consumption; xi) S&L Govt. Investment.

3. We now have a time series of Use and Make matrices for 65 sectors for 1947-2010, denoted $U^{BEA\_PL}(i,j,t)$ and $M^{BEA\_PL}(j,i,t)$, where *j* denotes industries and *i* denotes commodities. These matrices follow the conventions in the BEA 2002-Benchmark and we simplified the matrices by rearranging two non-produced items – Scrap, used and secondhand goods, and Rest of the World. The Make matrix has a column for Scrap showing which industries sell

scrap; we allocate this column to the diagonal of the Make matrix thus reclassifying the Scrap commodity as the selling industries' commodities. The Scrap row in each column of the Use table is then eliminated by distributing it to the other rows in that column according to the shares in the Scrap column of the Make table.

The Rest of the World row in the PCE column is the consumption that is attributed to tourist expenditures and counted as an export. Since the total tourism expenditures cannot be identified well, the official IO table put a negative entry in the cell $U^{BEA}(ROW, PCE)$, and a corresponding positive energy in $U^{BEA}(ROW, Export)$. The total of all the rows in the PCE column thus gives the correct domestic consumption, and the total of the export column gives the correct total exports. We eliminated this Rest of the World row by subtracting a proportional share from each commodity in the PCE column, and transferring them to the Export column. The total domestic consumption and total exports is thus preserved.

Denote these DJA simplified matrices by $U_{ijt}^{BEA-J65}$ and $M_{jit}^{BEA-J65}$.

4. The next step is to disaggregate the 65 sectors in the BEA-J65 tables to our 87-industry list that includes detail on the Information Technology, Electric Utility and other sectors. The splits are shown in Table A1; Mining except oil and gas is disaggregated to (4) Coal Mining and (5)Non-energy Mining; Computer and electronic products is disaggregated to (17) Computer and peripheral equipment, (18) Communications equipment, (20) Other electronic products, (19) Semiconductor and other electronic components; Publishing Industries is split into (49) Newspapers, periodical and book publishers, (50) Software publishing. For the energy accounts, Utilities is split into (7) Electric Utilities, (8) Gas Utilities and (9) Water systems; Government Enterprises is divided into Electric Utilities (82 and 84) and others; and General Government are also subdivided. Food and Tobacco is split into (27) Food and (28) Tobacco; Primary Metals into (13) Iron & Steel and (14) Non-ferrous metals; Other transportation equipment into (23) Aircraft and (24) Other Transportation Equipment; Apparel-Leather into (30) Apparel and (31) Leather; Chemicals into (36) Pharmaceuticals) and (35) Other Chemicals; Broadcasting into (52) Broadcasting and (53) Telecommunications; Other Services into (76) Automobile Repair, (78) Private households

and (77) Other services. To construct an account of household capital services that include consumer durables and owner-occupied housing we need to split Real Estate into (59) Real Estate-rental and (60) Real Estate-owner occupied housing. The shares used to disaggregate the BEA65 IO to DJA87 IO are derived from a variety of sources as described next.

As noted in the Introduction, the BEA provides estimates for output for 426 industries on its web site but not in the official publications since it is of poorer quality. These *GDP by Industry* accounts give the output and prices for 1998-2010 and include most of the DJA87 industries listed in Table A1. We however, need to split some of the BEA426 sectors further as described below.

The Office of Occupational Statistics and Employment Projections in the BLS provide time series of input-output tables for about 200 industries[10]. The latest series produced by this Office is for 1972-2010 covering 195 industries in NAICS. Data is provided for industry output, commodity output, industry output prices and commodity prices. An earlier series from the BLS (Chentrens and Andreassean 2001) provided a similar data set for 192 industries on the SIC-1987 basis covering 1983-2000, while a release in November 1997 covering 1977-1995 is for 185 sectors. These BLS data in SIC are used in Jorgenson, Ho and Stiroh (2005) and Jorgenson, Ho, Samuels and Stiroh (2007). We refer to these datasets as "BLSIO".

4.1 Creating an initial guess for RASing the USE and MAKE for DJA87

4.1.1. We use the BLSIO covering 1993 – 2010 for 190 NAICS industries to compute cell by cell shares for splitting the BEA65 industry groups. The links between BLSIO and DJA87 are shown in Table A1b. The following groups are split:

Mining except oil and gas; Utilities; Primary metal manufacturing; Computer and electronics; Other transportation equipment; Food, beverage and tobacco; Apparel and leather; Chemical manufacturing; Publishing industries; Broadcasting and telecom; Real estate; Other services except government

4.1.2. We first compress the BLSIO's USE and MAKE matrices for 190 industries to the two sets of classifications, BEA65 and DJA87; creating the matrices $U_{IJt}^{BLS;65}$, $M_{JIt}^{BLS;65}$,

[1010] Graham (2012) describes the data available at http://www.bls.gov/emp/ep_data_industry_out_and_emp.htm .

$U_{ijt}^{BLS;DJA87}$ and $M_{jit}^{BLS;DJA87}$. The share contributed by each DJA87 sector to the corresponding BEA65 group is then calculated as:

$$ushr_{ijt}^{87} = U_{ijt}^{BLS;DJA87} / U_{IJt}^{BLS;65}, \quad \text{for } i \in I, j \in J; \quad \text{t = 1993,2010.}$$

The shares are then applied to the BEA65 matrices to derive the initial guess:

$$USE1_{ijt}^{DJA87} = ushr_{ijt}^{87} * U_{IJt}^{BLS;65}$$

The notation USE1 signifies it as the initial guess of matrix USE. The above procedure applies to both the industry columns for j=1,2..87 as well as the final demand columns.

The initial guess of the 87-sector Make matrices, $MAKE1_{jit}^{DJA87}$, is similarly derived from $M_{JIt}^{BLS;65}$ and $M_{jit}^{BLS;DJA87}$.

4.1.3. JHS (2011) constructed a bridge to link the SIC data for 1960-1997 to NAICS for 98 industries. This was based on the 1997 employment bridge provided by the BLS, and the BLSIO dataset for 1993-2008 covering 197 NAICS sectors released in December 2009. The SIC based data for 1970-2005 is described in JHSS(2007). The NAICS IO data in JHS (2011) are used to break up the BEA65 industry groups for 1960–1997. For years 1947–1959, we use the 1960 cell by cell shares.

4.1.4. The information from the BLSIO in 4.1.2 do not give us shares to split Retail Trade into Retail motor vehicle trade and Retail non-motor vehicle (other) trade. For this sector we use data from the Economic Census (1997 Data from the economic census http://www.census.gov/prod/ec97/e97cs-8.pdf; 1992 Data from the economic census http://www.census.gov/prod/2/bus/retail/rc92-s-2.pdf; earlier Economic Censuses in 1987, 1982, 1977, 1972, 1963 and 1958 in hard copies only). These reports give us a time series of Retail Trade for 1993–2010, and we interpolate shares for the gap years to develop a time series of Retail Trade shares. We use the same shares for both rows and columns for Retail Trade.

4.1.5. To split State & Local Electric Utilities from total State & Local Enterprises in BLSIO we use the Benchmark Input-Output table for 2002 that gives us the utilities explicitly. This industry output goes to the “electric utilities” commodity together with private

electric utilities, thus USE(SL Elect, j)=0 for all *j*. We use the 2002 shares to split S&L Enterprises for all years.

4.1.6. There is no IO information to split up Federal Government into Federal Health and Federal Other, and we simply use the labor compensation that is in the BLSIO and in the labor database derived from the Population Censuses. The labor share for 1960-2010 is used to allocate the entire column for total Federal Government into Health and Other (see DJA 2008 for details).

4.1.7. For splitting the grouped cells in each of the State & Local Government columns in the USE, we use the DJA98 IO data in JHS (2011) for 1960–2008. To split group *I* in *USE(I,SL gov)*, we first note the contribution of total S&L Government sector to the health and education commodities in the MAKE table. The shares going to health and to education commodities are then used to split the Government row in the USE table.

4.2. Our next step is to create industry output, value-added and commodity output for the 87 NAICS industries to be used as control totals in the RAS procedure.

4.2.1. We first take the gross output for the BEA426 industries for 1998-2010 and aggregate them to DJA87 industries; for retail-motor vehicle and government health, we use the shares described in 4.1.4, 4.1.6 and 4.1.7 above. This gives $VQI_{j,t}^{DJA87}$, t=1988+. For 1972–1997, we use BLS output data for 200 NAICS industries and computed an output series $VQI_{jt}^{BLS-DJA87}$ by aggregating to the DJA87 industries. For 1947–1972 we use the BEA65 IO and labor compensation to estimate gross output, $VQI_{jt}^{BEA65-DJA87}$. We apply the annual growth of industry output in $VQI_{jt}^{BLS-DJA87}$ for 1972-1998 and extrapolated backwards from the gross output in 1998 given by BEA426. Then we apply the growth of $VQI_{jt}^{BEA65-DJA87}$ for 1947-72 to the 1972 output. This results in gross output for the DJA87 industries for 1947-2010, denoted as $VQI_{j,t}^{DJA87}$.

4.2.1.1. The BEA65 IO does not have enough detail for a one-to-one link to the DJA87. So for Mining, the Retail group and the Utilities group, we use the trend in the labor input share of gross output to split them. For example, to split Other Mining into Coal and Nonenergy mining:

$$l\_shr_{coal,1960} = VL_{coal,1960} / VQI_{coal,1960}$$

$$l\_shr_{\text{nonenergymining},1960} = VL_{\text{nonenergymining},1960} / VQI_{\text{nonenergymining},1960}$$

$$VQI^{1}_{coal,t} = l\_shr_{coal,t} / VL_{coal,t} \quad \text{for} \quad \text{t=1959,58,…47}$$

$$VQI^{1}_{J,t} = l\_shr_{J,t} / VL_{J,t} \qquad \text{J=nonenergymining}$$

$$VQI^{DJA87}_{coal,t} = \frac{VQI^{1}_{coal,t}}{VQI^{1}_{coal,t} + VQI^{1}_{\text{nonenergymining},t}} VQI^{BEA65}_{OtherMining,t}$$

4.2.1.2. The BLS NAICS series do not disaggregate out the State & Local government electric utilities and we turn to the older BLS output data covering 1972 – 2002 on an SIC basis that do give this sector's output.

4.2.2. To construct value added for the DJA87 industries, VA^{DJA87}_{jt}, we assume that value added is proportional to gross output in each group. That is, for industry j in group J,

$$VA1^{DJA87}_{jt} = \frac{VQI^{DJA87}_{jt}}{VQI^{BEA65}_{Jt}} VA^{BEA65}_{Jt} \qquad \text{j=coal; J=OtherMining}$$

For splitting *J*=Other Services, Retail Trade, Government; we use the shares described in (4.1) above. This gives us an initial guess of value added, we then scale them to total GDP to create a final time series of value-added for 1947–2010: $\sum_j VA^{DJA87}_{jt} = GDP_t$

4.2.3. Finally, we derive the commodity output by first scaling the initial guess of the MAKE matrix, $MAKE1^{DJA87}_{jit}$, from section 4.1.2 to the industry output in 4.2.1 to get the proper MAKE: $\sum_i MAKE^{DJA87}_{jit} = VQI^{DJA87}_{j,t}$

Then we sum down the columns of the scaled MAKE matrix to give the commodity output: $\sum_j MAKE^{DJA87}_{jit} = VQC^{DJA87}_{i,t}$

5. With the industry and commodity output for each sector we have the column and row targets to construct Use and Make matrices of dimension 87 x 87 for all years 1947-2010, which we denote

by U_{ijt}^{DJA87}. The initial guesses are the $USE1_{jit}^{DJA87}$ and $MAKE1_{jit}^{DJA87}$ matrices from 4.1 above. These are RAS'ed such that:

(i) For each group in the BEA65 classification, the values in the component cells in U_{ijt}^{DJA87} add up to the group cell in the BEA-J65 matrices. E.g., the sum over "Newspapers" and "Software" rows in each column *j* of U^{DJA87} must equal the value in $U^{BEA-J65}("Publishing", J)$ for the corresponding group *J*.

(ii) The sum of the columns in U^{DJA87} matches the industry output for the 87 industries derived in 4.2.1 ($VQI_{j,t}^{DJA87}$) and the sum of the rows matches the commodity output ($VQC_{i,t}^{DJA87}$). Similarly, the row and column sums of M^{DJA87} must match these totals.

(iii) The column sum of the final demand columns in the Use matches the PCE, Fixed Investment, Inventory etc. totals in the NIPA. This means that the sum of all the final demand columns is *GDP=C+I+G+X-M*.

(iv) The value added cells are left unchanged at the estimate given in 4.2.2 where $\sum_j VA_{jt}^{DJA87} = GDP_t$

A.3.2 Industry and commodity prices

The *GDP by Industry* data for 426 industries on the BEA's web site, as noted above, give output and prices for 1998-2010. We first aggregate over the 426 industries to obtain prices for our DJA98 classification for these years. As with all aggregation procedures used in our work we apply the Tornqvist index. We then further aggregate them to the 87 industries, or the BEA-J65 industries.

Next, we use the 87-sector Make matrices constructed in Step (5) of section A.3.1 above to derive commodity prices from these industry output prices.

For years prior to 1998 we turn to the BLS time series for output and prices noted above in A.3.1. We extrapolate prices for 1972–1997 using BLS industry data for 195 NAICS industries covering the period 1972-2008 released in July 2009. These BLS195 industries are first aggregated to the DJA87 industries with adjustments for the Retail and Government sub-sectors as described in

A.3.1. On examining the BLS prices we find that we need to replace their data for these sectors: Pipelines, Information and data processing, Computer systems design, Management of companies. We use the prices from the SIC dataset used in Jorgenson, Ho, Samuels and Stiroh (2007) instead.

For the years 1960-1972 we use the data in JHSS (2007) for 88 industries in the SIC that was bridged to the DJA98 NAICS in JHS (2011). Where there is not enough detail – Motor Vehicle Repair Services, Federal Electric Utilities, State-Local Electric Utilities – we simply use the corresponding group price.

For 1947-1960 we turn to the data for 51 SIC industries in Jorgenson, Gollop and Fraumeni (1987). These were allocated to the DJA87 industries using a simple correspondence such as allocating all of Primary Metals (SIC) to Primary Metals (NAICS).

The above results in a set of output prices for the DJA87 industries, $PI_{j,t}^{DJA87}$. Using the shares from the Make matrix, we then derived the domestic commodity prices:

(A.7) $$\ln PC_{i,t}^{DJA87} = \sum_{j} mshr_{jit} \ln PI_{j,t}^{DJA87}$$

A.3.3 Import prices

The price of the aggregate supply of a commodity is the weighted average of the domestic variety and the imported one. We thus need prices of imports of the corresponding 87 commodities. Of these 87, 15 are services with zero imports. Note that the conventions of the Use table give the value of imports of *i* inclusive of tariffs, and as a negative entry, and put the total value of duties collected as a positive number in the Wholesale Trade row ($U_{\text{Wholesale,Import}}^{BEA}$); with this system the column total for Imports is the import value of the U.S. in world prices and the row total for *i* is the domestic commodity output. That is, the column total is the M in GDP=C+I+G+X-M.

The main source of import price indices is the Bureau of Labor Statistics, Division of International Prices which has been compiling prices in NAICS for 2006 onwards[11]. Prior to that data

[11] The import prices are given at http://www.bls.gov/mxp/ .

is estimated for the SITC system, the Harmonized system and other classifications. The price indices are made available at very detailed levels and also at the 2-digit and 3-digit levels that we are concerned with in this study.

For the NAICS data during 2006-2010 the correspondence to our 70 commodities is straightforward for all the manufacturing groups. For service imports we turn to the estimates from the BEA given in the Balance of Payments accounts and NIPA (Table 4.2.4).

For the earlier 1977-2005 period when prices are given in the SITC we constructed a bridge between the 3-digit SITC codes and the DJA87 sectors. The prices at the 3-digit level were aggregated up using the import values from the BLSIO NAICS data for 1983 – 2000 covering 190 industries, BLSIO SIC data for 1983-2000 covering 192 industries, and BLSIO SIC data for 1977 – 1995 covering 185 industries. For the period prior to 1977 we use the import prices developed in Ho (1989) for 35 commodities.

The BLS indices are based on either f.o.b. or c.i.f. prices (see BLS Handbook of Methods[12], 1997, Chapter 15). This means that tariffs and duties are not included. Duties collected are estimated by the US International Trade Commission at detailed NAICS codes and also at 3- and 4-digit levels. (The data is available at the ITC web page: http://dataweb.usitc.gov/).

A.3.4 Supply Prices and Input Prices

The total supply of commodity *i* is the aggregate of the domestic and imported varieties:

(A.7) $$QS_{it} = f(QC_{it}, QM_{it})$$

We compute the price of total supply, PS_{it}, as the Tornqvist index of the domestic and import prices; PC_{it} from (A.7) and PM_{it} from section A.3.3. The values of commodity output and imports are those in the Use table, U_{ijt}^{DJA87}, given in section A.3.1. This PS_{it} is the price that consumers pay for their consumption goods and producers pay for their intermediate inputs. This is assumed to be common to all purchasers, i.e. we assume that industry *j* and industry *k* pays the same price for "Machinery".

[12] The Handbook is available at http://stats.bls.gov/opub/hom/homtoc.htm .

The price for total intermediate input for each industry *j* is, however, specific to each industry since we use information for the value of each commodity input:

$$\text{(A.8)} \quad \ln \frac{PZ_{jt}}{PZ_{jt-1}} = \sum_{i=1}^{87} \tfrac{1}{2}(w_{it}^{j} + w_{it-1}^{j}) \ln \frac{PS_{it}}{PS_{it-1}}; \qquad w_{it}^{j} = PS_{it} QP_{it}^{j} \,/\, \sum_{k} PS_{kt} QP_{kt}^{j}$$

References

Ball, Eldon, David Schimmelpfennig, and Sun Ling Wang. 2013. Is U.S. Agricultural Productivity Growth Slowing? *Applied Economic Perspectives and Policy* 35(3):435-450.

Brynjolfsson, Erik, and Adam Saunders. 2009. *Wired for Innovation: How Information Technology is Reshaping the Economy*. Cambridge MA: The MIT Press.

Bureau of Economic Analysis. 1986. "Improved Deflation of Purchase of Computers." *Survey of Current Business* 66(3):7-9.

Bureau of Economic Analysis. 2003. *Fixed Assets and Consumer Durable Goods in the United States, 1925-97*. September, Washington.

Bureau of Labor Statistics. 1983. *Trends in Multifactor Productivity, 1948-1981*. Washington DC: U.S. Government Printing Office.

Chentrens, Carl and Arthur Andreassean. 2001. Employment Outlook: 2000-2010. Layout and Description for 192-Order Input-Output Tables: 1983 through 2010 Historical and Projected 2010. U.S. Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections. November.

Domar, Evsey. 1961. "On the Measurement of Technological Change." *Economic Journal* 71(284): 709-729.

Donahoe, Matthew, Edward Morgan, Kevin Muck, and Ricky Stewart (2010), "Annual Industry Accounts: Advance Statistics on GDP by Industry for 2009, Revised Statistics for 1998-2008, Comprehensive Revision," *Survey of Current Business* 90(6), June, 14-20.

Graham, Richard. 2012. Employment Outlook: 2010-2020. Layout and Description for 195-Order Input-Output Tables: 1993 through 2010 Historical and Projected 2020. U.S. Bureau of Labor Statistics, Office of Occupational Statistics and Employment Projections.

Inter-Secretariat Working Group on the National Accounts (2009), "Capital Services and the National Accounts." *System of National Accounts 2008*, Vol. 2, Ch. 20. United Nations, NY: European Commission, International Monetary Fund, the Organisation for Economic Co-operation and Development, United Nations, and World Bank, 415-426. The pdf version is available at http://unstats.un.org/unsd/nationalaccount/SNA2008.pdf

Jorgenson, Dale W. 1990. Productivity and Economic Growth. In *Fifty Years of Economic Measurement*, eds. Ernst R. Berndt, and Jack E. Triplett, 19-118.

Jorgenson, Dale W., Frank M. Gollop, and Barbara M. Fraumeni. 1987. *Productivity and U.S. Economic Growth*. Cambridge, MA: Harvard University Press.

Jorgenson, Dale W., Mun S. Ho, and Jon D Samuels. "Information Technology and U.S. Productivity Growth: Evidence from a Prototype Industry Production Account," *Journal of Productivity Analysis*, 36(2):159-175, 2011.

Jorgenson, Dale W., Mun S. Ho, and Kevin J. Stiroh. 2005. Information Technology and the American Productivity Resurgence. *Economic Systems Research*. 19(3), 229-252, September.

Jorgenson, Dale W., Mun S. Ho, Jon D. Samuels and Kevin J. Stiroh. 2007. *Industry Origins of the American Growth Resurgence*. Cambridge, MA: The MIT Press.

Jorgenson, Dale W., and Marcel P. Timmer. 2009. "Structural Change in Advanced Nations: A New Set of Stylized Facts," Groningen, NL: Groningen Growth and Development Center, October.

Jorgenson, Dale W. and Kun-Young Yun. 2001. *Lifting the Burden: Tax Reform, the Cost of Capital, and U.S. Economic Growth*. Cambridge, MA: The MIT Press.

O'Mahony, Mary, and Marcel Timmer. 2009. "Output, Input, and Productivity Measures at the Industry Level: The EU KLEMS Database." *Economic Journal* 119(538): F374-F403.

Schreyer, Paul. 2001. *OECD Manual: Measuring Productivity: Measurement of Aggregate and Industry-Level Productivity Growth*. Paris: Organisation for Economic Development and Cooperation.

Schreyer, Paul. 2009. *OECD Manual: Measuring Capital*. Paris: Organisation for Economic Development and Cooperation.

Yuskavage, Robert E. and Yvon H. Pho. 2004. Gross Domestic Product by Industry for 1987-2000. *Survey of Current Business*. Bureau of Economic Analysis. Vol. 85(12), 33-53. December.

Yuskavage, Robert E. and Mahnaz Fahim-Nader. 2005. Gross Domestic Product by Industry for 1947-86. *Survey of Current Business*. Bureau of Economic Analysis. Vol. 84(11), 70-84. December.