Industrial Production and Capacity Utilization – G.17

FRB Estimates of Manufacturing Investment, Capital Stock, and Capital Services
June 13, 2019

In order to estimate industrial capacity for the G.17 statistical release on Industrial Production and Capacity Utilization, the Federal Reserve Board (FRB) produces annual estimates of investment, capital stocks, and capital services in chain-weighted real dollars for detailed industries within the manufacturing sector. In 2016, the FRB began publishing data on investment and capital stocks by broad asset type at the four-digit North American Industry Classification System (NAICS) level.[1] The 2019 release expands the level of industry detail and now includes capital services (capital input). In particular, the new data include estimates at the six-digit NAICS level for investment, capital stocks, and capital services, and also include the portions of investment and capital related to software.[2] The following note briefly describes the methodology underlying the construction of these data series.

Industry-Level Investment

Historical time series of annual industry-level estimates of current-dollar spending on new equipment and new structures are derived from multiple sources. For 1972 and forward, the principal sources of industry-level investment data are the Annual Survey of Manufactures (ASM) and the quinqennial Census of Manufactures (COM), both from the U.S. Census Bureau. Because it typically takes one to two years to go from collecting the data for an ASM or COM to publication, the FRB forecasts investment for the most recent years using indicators of manufacturing capital spending plans, lagged utilization rates, and internal staff estimates of broad investment categories.

For years prior to 1972, the FRB employs investment estimates from the Office of Business Analysis (OBA) at the Department of Commerce, which are available at a three-digit Standard Industrial Classification (SIC) basis. To share out these three-digit SIC investment figures to the four-digit level, the FRB uses information from Jack Faucett Associates, an

[1] These data have been used for some time in the NBER-CES Manufacturing Industry Database jointly published by the National Bureau of Economic Research and the U.S. Census Bureau's Center for Economic Studies.

[2] Capital stock and investment data are available beginning in 1952, with capital services for individual industries available beginning in 1953. For the portions of investment and capital related to software, data begin in 1959 for investment and capital stock and in 1960 for capital services.

economic consultancy. The four-digit SIC level investment data are subsequently converted to NAICS using industry-level concordances.

Asset-Level Investment

The FRB divides investment into thirty-six asset categories (thirty for equipment, five for structures, and one for software) based on data from the Bureau of Economic Analysis (BEA) on aggregate U.S. capital spending. For recent years, estimates are based on asset-level investment from the BEA's national income and product accounts (NIPA). Some published NIPA categories, however, are less detailed than the corresponding Federal Reserve asset categories; their data are allocated to the more detailed FRB categories based on historical shares in the BEA's *Fixed Assets and Consumer Durable Goods in the United States* (FACDG).[3] For years prior to 1992, the estimates are based on the BEA's wealth stock models published in FACDG or on the earlier models published in *Fixed Reproducible Tangible Wealth in the United States, 1925-89* (FRTW).[4] For years for which NIPA data are not yet available, the FRB forecasts asset-level investment.

Combining the Industry-Level and Asset-Level Estimates

Because detailed data for asset-by-industry investment are available for only select years, the Federal Reserve estimates annual time series for asset-by-industry investment by combining the annual industry spending totals on new equipment and on new structures with the annual economy-wide capital spending by detailed asset categories, along with their corresponding price deflators. This asset decomposition of industry-level investment is estimated separately for equipment and for structures.

Data on asset-by-industry investment were previously available in the BEA capital flow tables (CFTs), which contained detailed parsing of hundreds of asset types across manufacturing and non-manufacturing sectors. Because the CFTs are only available for select years—and notably ceased to be published in 1997—the FRB creates an *initial* estimate of asset-by-industry investment for non-CFT years by interpolating between adjacent CFT shares; more recent years

[3] "Fixed Assets and Consumer Durable Goods for 1995–2005," *Survey of Current Business*, September 2006, pp.22-33. In addition, the most up-to-date data may be found at http://www.bea.gov/national/FA2004/Index.asp.

[4] *Fixed Reproducible Tangible Wealth in the United States, 1925–89*. Bureau of Economic Analysis (Washington: U.S. Government Printing Office).

use the 1997 CFT's distribution as an *initial* estimate. The FRB also makes use of the annual data on investment in certain asset classes published in the ASM and COM.

For years when the CFT is unavailable, the *final* FRB estimates for the asset composition of industry investment results from using a biproportional matrix-balancing technique, more commonly called RASing.[5] In brief, if one considers the by-asset, by-industry composition of investment for a specific year as a matrix in which the i,j^{th} element is the amount of investment by industry *j* made in asset *i*, then RASing will yield a unique final non-negative matrix of industry-by-asset investment flows such that the components of the matrix sum to appropriate industry- and asset-level totals.[6]

FRB-PIMS Estimates of Capital Stocks

The FRB uses the investment data outlined above to construct industry-by-asset net capital stocks, defined as the accumulation of past gross investment less the accumulation of past depreciation. These capital stock estimates are based on the FRB's perpetual inventory model (FRB-PIMS). FRB-PIMS is similar to a standard PIMS model, but does not use a constant rate of decline in productive capability. Rather, the FRB-PIMS assumes that efficiency declines less for a relatively new asset than it does for an asset nearer the end of its expected useful life. The non-constant decline rate combines two separate effects: discards and decay. The discards effect is a probability-based estimate of the actual service life of an asset, conditional on a mean service life and a distribution around the asset's expected service life. The decay effect is the relative loss of economic efficiency of the asset as it ages. The joint effects of discard and decay are combined into the age-efficiency function used in the FRB-PIMS.[7]

As described in Gilbert and Mohr (1996), the FRB-PIMS formula for the net capital stock at time *t* for asset *j* that allows for non-constant rates of efficiency decline is

(1) $$K_{j,t}^{N} = \sum_{i=0}^{S_j} \phi_{j,i} I_{j,t-i}^{G} \ ,$$

[5] Michael Bacharach (1965), "Estimating Nonnegative Matrices from Marginal Data," *International Economic Review*, vol. 6 (3), pp. 294-310.

[6] More detail on the RASing procedure can be found in Gilbert, Charles and Mike Mohr (1996), "Capital Stock Estimates for Manufacturing Industries: Methods and Data," Working Paper. Available online at https://www.federalreserve.gov/releases/g17/CapitalStockDocLatest.pdf.

[7] The expected efficiency of an *a*-year-old asset as a share of the efficiency of a brand new asset—that is, the proportion of economic efficiency remaining in an *a*-year-old asset is given by $\phi_a = \int_{-.5\bar{S}}^{.5\bar{S}} \kappa\left(a \mid S, \beta\right) P_D\left(S \mid \bar{S}, \sigma\right) dS$.

where $\phi_{j,i}$ represents the proportion of economic efficiency remaining in an *i*-year-old asset and accounts for the combined effects of discard and decay, and S_j is the maximum service life of asset of type *j*. Equation (1) can be rewritten in terms of increments to the net capital stock from net investment flows:

(2) $$K^N_{j,t} = K^N_{j,t-1} + I^N_{j,t},$$

where net investment is the difference between gross investment flows and replacement investment,

(3) $$I^N_{j,t} = I^G_{j,t} - I^R_{j,t},$$

so

(4) $$K^N_{j,t} = K^N_{j,t-1} + I^G_{j,t} - I^R_{j,t}.$$

Defining $\omega_{j,i}$ as the amount by which the economic efficiency of an asset is reduced between ages *i*-1 and *i*—the combined effects of discard and decay—replacement investment is the sum of the incremental loss of economic efficiency between years *t*-1 and *t* in each investment vintage: [8]

(5) $$I^R_{j,t} = \sum_{i=0}^{S_j} \omega_{j,i} I^G_{j,t-i}.$$

Operationally, given a time series of gross investment flows in the j^{th} asset type, $\{I^G_{j,t}\}_{t=0}^{T}$, and given the assumptions for the stochastic mean service life and beta decay that yield the sequence of increments to economic efficiency loss over the life of an asset, $\{\omega_{j,i}\}_{i=0}^{S_j}$, replacement investment is calculated according to equation (5). Given equation (5) and assuming $K^N_{j,0} = I^N_{j,0}$, the time series of net capital stocks is constructed according to equation (4).[9]

The service lives for the various assets are chosen from the BLS multifactor productivity system. For some assets, the service life varies by three-digit NAICS industry. For a few assets, a discrete change in the service life occurs at some calendar date (such as aircraft, which have a mean service life of 15 years before 1960 and 19 years thereafter).

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[8] Therefore, $\phi_{j,i} = 1 - \sum_{k=1}^{i} \omega_{j,k}$ in equation (1).

[9] The time series of investment flows begins far enough in the past so that by the early 1950s, the level of the capital stock does not depend on the initial investment flows for any asset category.

An industry-level capital stock is obtained by aggregating asset-level stocks using chain-weighting procedure with BEA investment prices.

Construction of Capital Services

Capital services (also known as capital input) reflect the flow of services derived from the net stocks of productive assets. To create capital services for a given industry, the FRB aggregates asset-level capital stocks using a Tornqvist index method with implicit rental prices as weights. As stated in the primary source for the BLS method of constructing measures of capital, "The 'implicit rental price' or 'user cost' of capital is based on the neoclassical principle that inputs should be aggregated using weights that reflect their marginal products."[10] Indeed, because capital services more closely reflect the concept of the marginal product of capital than the total capital stock, a measure of capital services is a key independent variable in the FRB's models of industrial capacity. For this reason, the FRB began publishing its estimates of capital services in 2019.

The rental price formula for a particular asset is derived from a simple neoclassical model in which the price of an asset is assumed to be the present discounted value of the expected flow of services from that asset over its lifetime.[11] It is equivalent to the rent one would be willing to pay to get the same flow of services as would be obtained by purchasing the asset. The rental price takes into account asset-specific depreciation, expected price declines, and tax treatment of capital. The rental price formula is

$$p_{j,t}^{R} = p_{j,t}\left(r + \delta_j - \dot{p}_{j,t}^{rel} \big/ p_{j,t}^{rel}\right)\tau_{j,t}, \tag{6}$$

where p is the deflator for the asset, r is a rate of return, δ is a deprecation rate, $\dot{p}_{j,t}^{rel} \big/ p_{j,t}^{rel}$ is a real capital gains-capital loss term (based on the asset deflator relative to the GDP deflator), and τ captures the effects of various tax considerations.

[10] U.S. Department of Labor (1983), "Trends in Multifactor Productivity, 1948-1981," Bulletin 2178.
[11] Hall, Robert, and Dale Jorgenson (1967), "Tax Policy and Investment Behavior," *American Economic Review*, vol. 57 (3), pp. 391-414.