Capital Stock Turnover in Industry: Is There a Near-Term Opportunity to Improve Efficiency?

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ABSTRACT

Investment and capital stock decision-making is reasonably well understood, but quantitative evidence of how industries behave is in short supply. This study examines investment and capital stock data for major energy-intensive industries, and has two objectives.

The first objective of this study is to understand the age profile of equipment because this profile determines how rapidly capital becomes obsolete (either as a result of reaching its effective lifetime or because of economic factors). A second objective is to indicate the rules (tax lives, depreciation schedules, etc.) that affect decision-making processes that might be easily changed to alter decision making. We know that the basic industries – forest products, chemicals, nonmetallic minerals, primary metals, mining and agriculture – are both capital- and energy-intensive. How rapidly energy intensity changes depends, in large measure, on how rapidly new capital substitutes for old. This process occurs continuously.

Recent data on capital assets are used to characterize capital in energy-intensive industries and to develop age profiles for capital purchases in 1992. The decision making about the purchase of capital good is then examined, both from a capital budgeting perspective and from an economic perspective. One important factor in this choice is the tax treatment of capital, which has been modified frequently since the 1950s. Accordingly, changes in tax rules are examined to see what, if any, impact these changes have had on investment in energy intensive industries.

The age profile of capital stocks are then examined to demonstrate how these age profiles can affect energy consumption in industry.

Introduction

U. S. industry purchases billions of dollars of capital equipment each year and produces about 20% of the economy's output. This new capital equipment is typically more efficient than the equipment it replaces, so part of the improvement in efficiency each year is the result of scrapping old capital and replacing it with new capital – capital stock turnover. Intuition suggests that the more rapidly stock turns over, the more rapidly the energy efficiency of industry would change. The major purpose of this paper is to explore that intuition with information on capital stocks, an understanding of the factors that affect capital decision making in industry, and information about the tax treatment of capital.

The paper begins with a characterization of existing capital used in manufacturing, with an emphasis on the energy-intensive sectors. Data from the capital flows table of the 1992 input-output table of the U. S. economy are used to construct an age profile of equipment used in manufacturing. Attention is then turned to the factors that affect decision-making, both from a capital budgeting and an economic theory perspective. From this discussion it becomes clear that the tax treatment of capital is one important consideration, so changes in tax laws that have occurred since 1950 are surveyed. Then the age profile of capital stock is examined, under current tax treatment, to see what effect different levels of market penetration and ages will have on the energy-efficiency of capital stock. The final section draws some tentative conclusions.

An Overview of Capital Stock in Energy-Intensive Industries

Figure 1 shows the capital stock for all of manufacturing for the period 1947 through 1998, and for the production of durable and nondurable manufactures, in 1996 dollars. In manufacturing alone, the value of all equipment and structures was about $1,600 billion (as reported in Figure 1, or $1.6 trillion), with slightly more capital for durable manufacturing than for nondurables. The growth of the capital stock appears to have been most rapid during 1995-1998 and over the period 1963 to 1981.

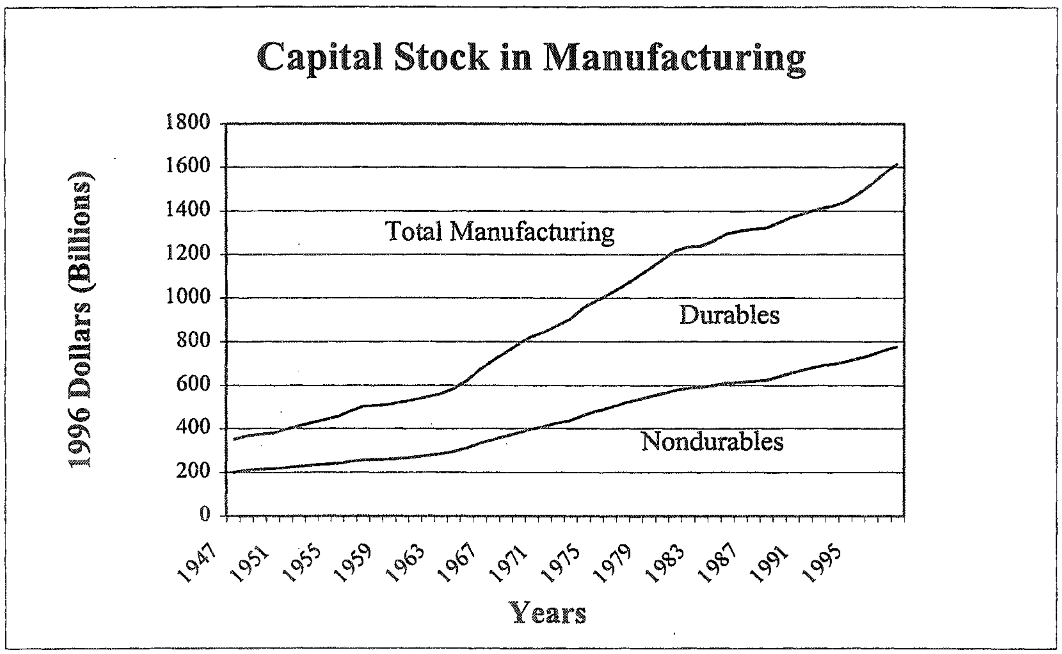

Figure 1. Capital Stock, Total Manufacturing, 1947 to 1998

Capital Stock by Industry

Figure 2 reports the capital stock for six energy intensive industries – Forest products [a combination of SIC 24 (Wood products) and SIC 26 (Paper and allied products)]; Chemicals (SIC 28); Petroleum and related products (SIC 29); Stone, clay and glass (SIC 32); Primary metals (SIC 33); and Fabricated metal products (SIC 34). Clearly Chemicals has the greatest invested capital, at about $225 billion, with Forest products edging above Primary metals in the four year to 1998, in the range of $130-$137 billion. Forest products and Fabricated metal capital stock has grown steadily over this period, with Chemicals growing quite rapidly except for the period from 1980-1986.

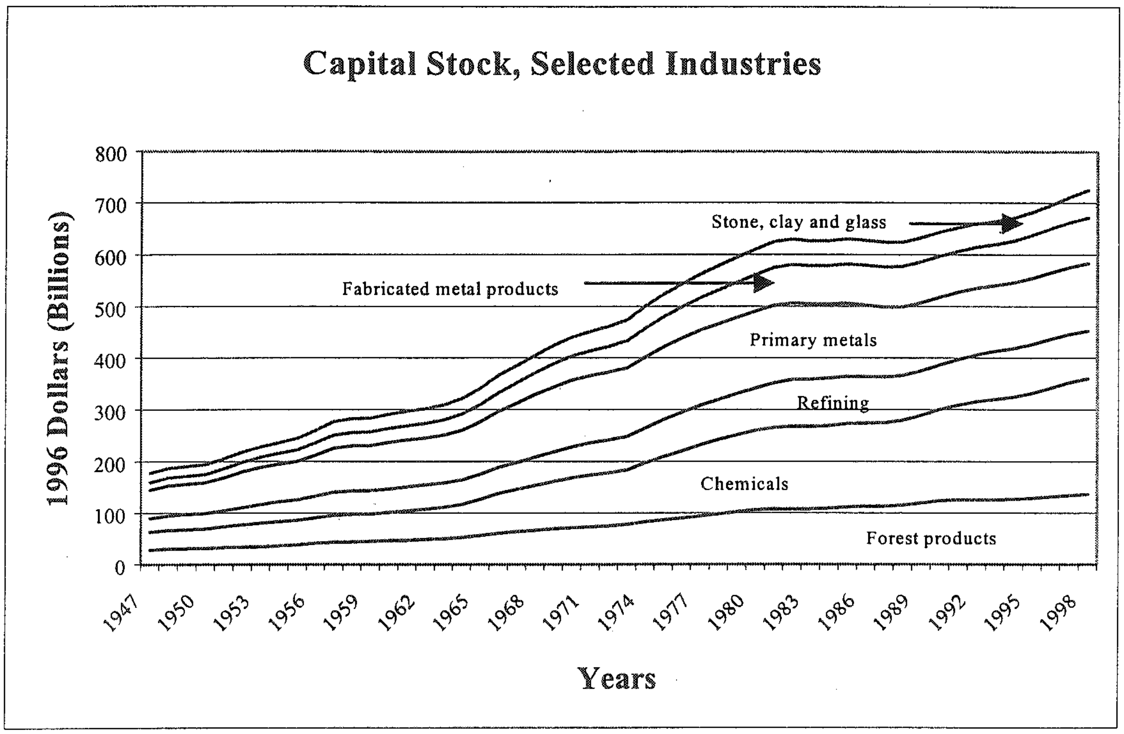

Figure 2. Capital Stock, Selected Industries, 1947-1998

Over the period 1980 to 1998, Petroleum refining, Stone, clay and glass, and Primary metals have all shown periods of attrition of capital stock, with Primary metals declining from about $150 billion in 1980 to about $130 billion in 1998. Stone, clay, and glass capital reached $50 billion in 1980, then decline slowly, only reaching that value again in 1997 and a further increment in 1998. Petroleum refining peaked in 1983 at $91.4 billion, declined, recovered to a peak of about $95 billion, but in 1998 was down to $92.5 billion. These six industries account for about $700 billion in capital stock, or 44% of total manufacturing capital stock in 1998.

The capital stock accounts are estimated periodically by the Bureau of Economic Analysis (BEA) of the U. S. Department of Commerce. These accounts have recently undergone substantial revisions, with new estimates of depreciation and services lives (see Fraumeni 1997). The latest revisions are reported in (BEA 2000). The level of detail reported is mostly at the 2-Digit SIC level (Office of Management and Budget, 1987), with additional detail for the transportation equipment sector. Table 5 in (Herman 2000) reports current cost estimates of the net stock of private fixed assets by industry and Table 6 reports chained quantity indexes net stock using 1996 as a base year. By multiplying this quantity index by 1996-dollar values, an estimate of the constant dollar net stock of assets can be estimated. The full series from 1947 to 1998 is available on the BEA's web site. The series shown in Figures 1 and 2 are from that set of data.

Equipment Lives

More detailed data by industry is available in the capital flow table (CFT) of the input-output (I/O) statistics also reported in the *Survey of Current Business*, with the 1992 CFT reported in (Bonds & Aylor 1998). Although a CFT was never published for the 1987 I/O, the commodity composition of producers durable equipment expenditures is available on the BEA web site. Associated with the equipment commodities are service lives and depreciation rates, so each industry's purchases of durable equipment can be used as weights to construct an implied service life for the purchases in that year, assuming a single 1.65 declining balance method of calculating the depreciation. The estimates of these service lives for 22 industries[1] are reported in Figure 3.

It is interesting to note that equipment purchases in 1992 varied considerably by industry, with instruments (SIC 38) purchasing equipment that averages less than 9 years of service life while textiles (SIC 22) purchased equipment with services lives of about 14 years. The average for all industry is 11.5 years. The implied service lives of energy intensity industries shown in Figure 2 are 12.3 for Wood products, 13.1 for Pulp and paper, 13 for Forest products; 11.3 for Chemicals; 12.5 for Petroleum refining; 13 for Stone, clay and glass; and 13 for Primary metals. These are show by the clear bars in Figure 3. Note that the combined industry, Forest products, is shown in Figure 3 as the clear bar after SIC 26.

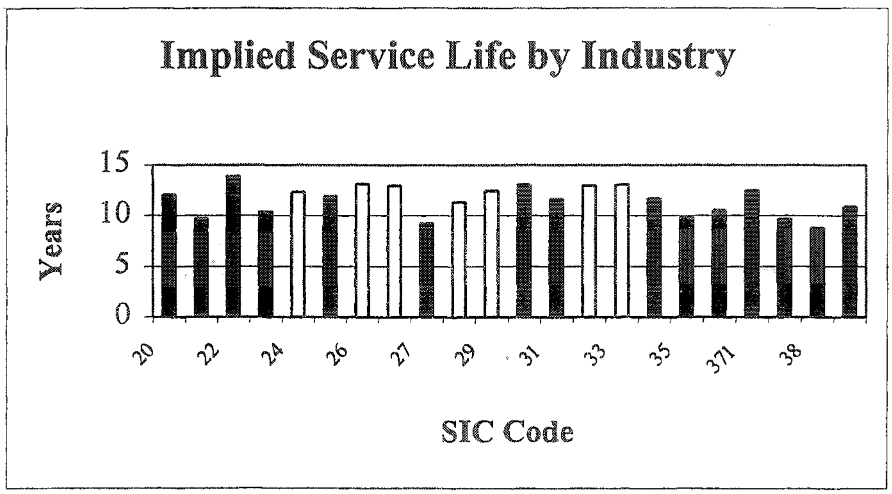

Figure 3. Implied Service Life of Equipment, by SIC, 1992

It is important to differentiate between investment purchases in a particular year and the stock of equipment, since expenditures for different types of equipment may vary from one year to the next. It is also important to differentiate between service lives and age of equipment. How long lived this equipment is will determine the opportunity set of policy options available for improving efficiency of industrial equipment. The service life is a construct associated with depreciation schedules that may reflect economic life.

[1] These are mostly 2-digit industries, but there is one 3-digit – 371 is motor vehicles and motor vehicle equipment – and what is labeled as 372 is the remainder of SIC 37. Forest products, between 26 and 27, is the sum of two 2-digit industries, SIC 24 and SIC 26.

The capital stock of industry can be characterized at this level of detail because the data exist and are reported at this level of detail. A prior publication, (BEA, 1999) reported capital stocks and equipment lives prior to the revision used to create Figures 1 and 2. Equipment lives reported in the prior publication are averages of all equipment (not just a single year's purchases) and generally show lower service lives than Figure 3, (although SIC 33, Primary metals, was longer by nearly a year). Anecdotal evidence suggests that some industries have equipment that is substantially older than shown in Figure 3. Integrated steel mills (none of which has been build since the early 1950s) have blast furnaces that survive for decades. Modifications and refurbishing may change the efficiency and the capacity of these furnaces, but they remain in place and are used for many decades. The Portland Cement association reports the ages of kilns for cement plants in member companies, and many of these are decades old. One kiln in Spokane, Washington, for example, is still operating though built in 1919. This equipment would not be reflected in the capital stock data if the kiln or blast furnace was fully amortized.

Generally, however, one can only infer the stock from assumptions about the service lives (and by assumption the effective or economic lives) of equipment, depreciation rates, and investments. There have been rare surveys of specific types of equipment (e.g., motors in the early 1980s), but nothing that would allow one to benchmark the existing physical stock with the actual equipment resident in plants and producing the output of manufacturing. We simply do not know what is really out there. But we do know a lot about the factors that affect the decision to purchase that equipment.

Investment and Factors that Affect the Decision to Purchase Capital

There are alternative ways of characterizing what happens in a firm when a capital decision is made, and all of these provide some insight into what factors are important. There is a rich literature on capital budgeting that characterizes the alternative ways of calculating the value of an investment. The economic theory that focuses on investment points to the key factors that may be influenced by policy. Various surveys have also been conducted that ask managers in firms what factors are important to the decision logic. After surveying the tools used in evaluating investments, the economic literature on investment and some of the important topics considered in this literature is briefly surveyed.

Capital Budgeting and Evaluating Investments

The main criteria used by industry to evaluate potential capital investments include (net) present value, benefit-cost ratios, required revenue, internal rates of return, levelized costs and payback periods. A brief synopsis of each of these follows.

(Net) present value (NPV or PV): defined as the value of costs, benefits or the difference between the two when the time value of money is taken into account. The calculation yields NPV if the difference between benefits and costs is used as the metric; it is PV if either costs or benefits alone is used. In most cases, if the NPV is positive, the benefit-cost ratio exceeds one.

Benefit-cost ratio: the ratio constructed by dividing the PV of benefits by the PV of costs; if the ratio exceeds one, then there is positive benefit over cost. The ratio can be constructed in two ways: by putting both costs and benefits on a PV basis, or by annualizing the capital costs and performing the calculation on a one-year basis (McRae & Dudas 1977).

Required revenue: defined as the levelized annual required revenues (i.e., benefits) to cover the sum of the levelized annual operating costs (fuel and operating and maintenance costs) and the annualized costs associated with investment. This criteria is typically used by utilities in calculating revenue requirements for new utility generation facilities. In this context, the levelized investment costs take into account tax rates, tax credits, cost of capital, salvage value, financing and insurance costs, etc. Under a regulatory regime that attempts to limit return on investment, this is an appropriate approach.

Internal rate of return (IRR): defined as the discount rate that equates the PV of benefits with the PV of costs. The calculation is similar to NPV calculation, but done iteratively until a value for the IRR is obtained for which NPV is zero. This calculated rate, called the IRR, is typically compared with a "hurdle" rate that must be exceeded in order for the investment to undertaken.

Levelized cost: a PV calculation for the entire life-cycle of a piece of equipment, taking into account the salvage or scrap value of the equipment (alternatively, the disposal costs) at the end of its useful life, put on an annual basis. These costs are levelized to compare the costs of equipment with different service lives. The levelization technique is similar to the capital recovery factor (CRF) or uniform sinking fund method used in other approaches. Levelized costs can be compared with the levelized PV of energy savings or benefits.

Payback period: in its simplest form, defined as the capital investment divided by the annual savings. To take into account the time value of money, the payback period is calculated as the PV of the actual period using an appropriate discount rate.

A more detailed discussion of these topics can be found in almost any treatment of capital budgeting (McChesney et al. 1982, Thuesen, Fabrycky & Theusen 1977 and Witte, Schmidt & Brown 1988).

Investment in Economic Theory

The treatment of investment in economic theory, at least in modern times, can be characterized as Keynesian or neoclassical. Both of these approaches recognize that capital decisions are made under conditions of uncertainty and that once made, may lock the firm into the chosen technology for some time. One critical factor, depreciation, is a vital element of this decision, and is briefly discussed. Another important factor is how tax law treats depreciation allowances, so the evolution of that tax treatment is also briefly discussed. Further details are available in any good text on investment; e.g., (Nickell, 1978) or (Dixit and Pindyck, 1994).

The Keynesian approach. Investment is considered as a business decision to move the firm from its current position to one where it is using the optimal amount of capital, and that optimal level is dependent on production levels and expected sales. The optimal level of capital (k^*) is defined by the expected production, factor prices and technology, so any change in factor prices – labor costs, energy costs, material costs, etc. – will change k^* and thus change current investment. It is assumed that the transition from the current capital stock (k) to the optimal stock is only partially accomplished in any given period, (because the adjustment process involves costs, or because of changes in the production technology or factor prices) so k^* is never fully reached. The critical variable is production: as output increased, greater investment is needed to reach that elusive k^*, which is know as the accelerator theory of investment. Algebraically, investment is:

$$I_t = \Delta k = (1-\lambda)\,(k_t^* - k_{t-1}) \qquad (1)$$

That is, investment in the current period is based on the difference between the optimal capital stock in the current period (k_t^*) and actual capital stock in the previous period (k_{t-1}), with λ being the adjustment factor, since Equation (1) can be put in the form:

$$k_t = \lambda\, k_{t-1} + (1 - \lambda)\, k_t^*$$

The accelerator theory of investment had appeal in explaining business cycles and why, during depressions, very little investment occurred. While this approach has a long and distinguished history, it has been largely supplanted by the neoclassical theory of investment.

The neoclassical theory of investment. While the Keynesian approach explains investment as a movement toward desired stock of capital, the neoclassical theory treats capital similar to the way it treats labor. What is valuable about capital is not the stock, or the replacement to that stock, but rather the services rendered by that stock of capital. This treats capital in a way that is symmetric with the treatment of human beings: it is not the number of laborers that is important (the stock of human capital), but rather the services rendered by those employees that is important to the production process. For capital services, the analogy to the wage rate for labor is the "user cost" or rental rate of capital. Following Hall and Jorgenson (1967), this is a function of price of capital relative to the price of output, an appropriate interest rate, the depreciation rate of capital, the rate of change of the relative price of capital, the corporate tax rate, any tax credits for capital expenditure, and the net present value of depreciation allowances per dollar of expenditure on capital. In algebraic terms:

$$C_t = P_t\,(R_t + \delta - \Delta P_t/ P_t)\,[(1 - ITC - \tau * DEP)/(1 - \tau)] \qquad (2)$$

where C is the rental rate of capital, P is the price of capital relative to the price of output, δ is the economic rate of depreciation, the last term in the first parentheses is the percentage rate of change in capital prices relative to output, ITC is any investment tax credit applicable, DEP is the present value of depreciation allowances for a dollar of investment, and τ is the corporate tax rate.

Part of the reason for the success of the neoclassical approach is treatment of those factors that play an important role in determining investment. The inclusion of corporate tax rates, the differentiation between economic depreciation and the net present value of depreciation allowances are now theoretically based, rather than being introduced as *ad hoc*, possibly important, variables. Among the most important of these variables is depreciation.

The treatment of depreciation. As capital goods are used, they deteriorate, even if that deterioration is not readily evident. Economic depreciation is the annual loss in financial value, possibly due to deterioration, of the capital good over time that must be subtracted annually from gross revenues to determine the income accruing from the asset. Attempts to measure this depreciation are frustrated by the fact that most firms own, rather than rent, capital goods. With the exception of goods that are easily moved and traded, markets for used capital goods are thin. Technical progress normally means that capital goods acquired in one time period will have somewhat better characteristics than capital acquired in an earlier period. Still, it is important to measure depreciation both to understand the contribution of capital to production and to correctly measure national income and wealth.

Both the theory of depreciation (Baumol 1971, Hall & Jorgenson 1967, Jorgenson 1963) and its measurement (Jorgenson 1996, Hulten & Wykoff 1981, Wykoff 1989) are treated by Fraumeni (1997) in a discussion of depreciation in the national accounts. In this article she reports rates of depreciation and service lives for the categories of equipment used to produce Figure 3, and this is the basis for estimates of capital stock that are shown in Figures 1 and 2. In the section after the discussion of tax changes, we show how the service lives of equipment can affect the change in efficiency of the capital stock in industry.

Changes in taxes affecting capital purchases. Since the end of World War II, Congress has made numerous changes to the tax code that affect corporations' decision to invest. The major changes are identified below; further detail is available from (Tempalski 1998); it should be noted that changes relating to capital gains, which can affect the cost of capital, are not included. This partial collection of revisions suggests considerable inconsistency of tax treatment that corporations faced over the last 50 years. This inconsistent treatment of capital investment add a great deal of uncertainty to the corporation capital decision making process.

Major changes in the treatment of depreciation include actions that change the tax treatment of corporate profits as well as changes directly to the treatment of depreciation. Corporate tax rates have been changed by the revenue acts in 1950, 1951, 1954, 1964, 1976, 1980, 1986 and 1993. The investment tax credit was first established in 1962 (at 7%), but then repealed in 1969, reinstated in 1971, changed in 1975, modified again in 1976, and finally repealed in 1986. The treatment of depreciation under the tax code has also been subject to frequent alteration. Depreciation schedules were changes in 1954, double-declining balance was introduced in 1971, accelerated recovery was introduced in 1981, but then changed in 1982 and again in 1997. In addition, some minor tax changes, such as the schedule of estimated tax payments, has frequently been changed as well.

The message is that change is frequent enough to preclude any serious long-term planning on the part of corporate executives, based on current tax law. With these frequent changes, a decision maker in a corporation might be especially wary of committing to capital decisions based entirely on the *current* tax treatment of capital. This may explain why it is so difficult to empirically attach an effect to small changes in either corporate tax rates or special treatment of investment.

The tax treatment of investments is suppose to reflect service lives of equipment, and in some cases, it may. Generally this is not true, even though services lives can have a profound effect on the efficiency of the capital stock.

The Effect of Service Lives on Efficiency

Consider two different pieces of equipment, for convenience labeled A and B, that produce precisely the same output but have different service lives – B lasts longer than A. Equipment A currently has nearly the entire share of capital stock, but there is an efficiency gain that accrues from using B, so B will penetrate the market over time. As equipment B penetrates the market, what effect will this difference in service lives have on the energy efficiency of production?

The hypothetical characteristics of equipment A and B are shown in Table 1.

Table 1. Characteristics of Equipment A and B

Characteristics	Equipment A	Equipment B
First Cost	$80,000	$100,000
O&M Cost	$1,000	$900
Life	10	12
Energy Cost	$50,000	$45,000
Depreciation	0.165	0.1375
Initial Stock	$50,000,000	$1,000,000
Units Produced	1000	1000
Cost of Capital	12%	12%
Capital Recovery Factor	0.177	0.1614
Annual Cost	$65,160	$62,040

Figure 4, below, shows how the age difference affects the equilibrium of the equipment stocks when equipment B has a 55% penetration of the new sales market in each year after its introduction (shown as the two lines at the bottom of the figure). It takes 11 years before equipment stocks are equalized between A and B, and about 20 more years before the ratio of stock between equipment A and B are equalized at about 40% and 60% of total stock, respectively. This uses the depreciation rates shown in Table 1, which is based on a 1.65 declining balance for the two different service lives. Energy costs to product the 635,000 units of output are $31.7 million, but this number declines to $30.1 million in equilibrium, a 5.1% decline in energy consumption.

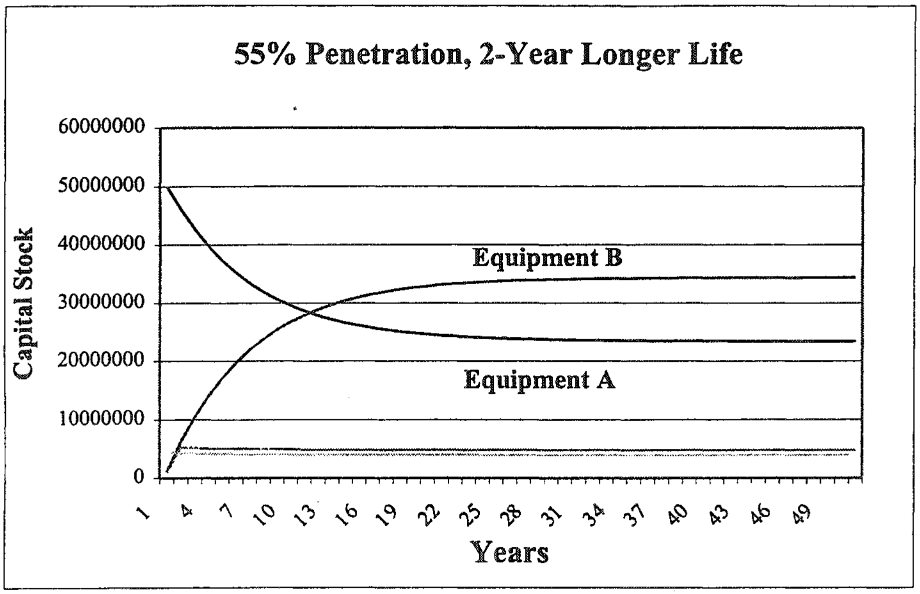

Figure 4. Stock of Two Assets based on Market Penetration and Service Life Difference

Table 2, below, reports eight cases of the effect of a combination of age difference and penetration rates on the year in which the stocks of equipment A and B are equal, their equilibrium stock share, and the percentage savings of energy when final stock shares have equilibrated.

Table 2. Energy Savings and Other Characteristics as a Result of Differences in Ages and Penetration Rates

Penetration Rate for B	Age Difference	Stock Equal in Year	Fraction of Stock for B	Energy Savings (%)
45	2	---	49.5	4.2
50	2	16	55	4.6
55	2	11	59	5.1
60	2	9	64	5.7
40	4	29	50	4.2
50	4	10	60	5.1
55	4	8	65	5.6
60	4	7	69	6.1

The energy savings from the substitution of equipment B for A will never quite match the 10% savings of B over A unless the penetration is 100%, which by assumption it is not. But this example shows that both age of equipment and penetration of current market sales will affect the ultimate energy intensity of production. From Equation (2) above, we also know that tax rates, both corporate and investment-specific, and depreciation rules will also have an effect on the user cost of capital and thus will affect the decision to purchase new equipment.

Conclusions

From an energy-efficiency perspective, there is a tension between a desire to have more efficient equipment dominate the stock of capital (the longer the life of a capital good, the more it dominates the stock) and a desire to have capital turn over rapidly (i.e., be short lived) so that the equipment becomes more efficient more quickly. It is clear that if a piece of equipment is far superior in terms of its energy-efficiency characteristics, then the longer lived that equipment, the more impact it will have on the efficiency of the stock as a whole. But if it is inferior from an energy-efficiency perspective, then a long life means that it will be difficult to displace, and the more efficient equipment might never dominate, even though it captures a large share of the market. If the case were as extreme as the difference between compact fluorescent (CFL) bulbs and incandescent bulbs (a 10-year difference in life), CFLs capturing just a 15% of current sales would assure that nearly 67% of the total stock would be CFLs over time. If the efficiencies of CLF and incandescent bulbs were reversed, it would be very difficult to improve the energy efficiency of the capital stock.

While understanding this tension is important, it is clear that anything that can be done to encourage the adoption of more efficient equipment should be promoted. Exactly how to do this is not clear, but it is clear that further research on this topic is needed. One topic that needs to be examined is how differences in economic lives of equipment and depreciation (or tax) service lives affect the decision to replace existing equipment. A second topic is to look at how other market economies may encourage more rapid capital turnover.

Finally, to answer the question posed by the title of this paper, the answer is both yes and no. Yes, there are short-term opportunities to reduce uncertainty through information programs and through research and development both to reduce costs of energy-efficient capital and to extend the lives of energy-efficient equipment. But also no, there are no magic bullets and it is ill advised to use tax law to encourage accelerated investment in energy-efficient equipment.

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