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Schumpeterian Profits and the Alchemist Fallacy Revised[1]

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Schumpeterian Profits and the Alchemist Fallacy

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Abstract

The present study examines the importance of Schumpeterian profits in the United States economy. Schumpeterian profits are defined as those profits that arise when firms are able to appropriate the returns from innovative activity. The paper derives the underlying equations for Schumpeterian profits. It then estimates the value of these profits for the non-farm business economy and for major industries. It concludes that only a miniscule fraction of the social returns from technological advances over the 1948-2001 period was captured by producers, indicating that most of the benefits of technological change are passed on to consumers rather than captured by producers. These results indicate that the bubble of new-economy stocks in the 1990s resulted from the alchemist fallacy.

KEY WORDS: Shumpeter, profits, innovation

JEL CLASSIFICATIONS: 030, 031, 04

Alchemy was an ancient art devoted to discovering a miraculous substance that would transmute common metals into gold. Most recently, this philosophy resurfaced with the view that the "new economy" could spin rapid technological change into profits and fantastic stock values.

Many have scoffed at the idea that base metals can be transmuted into precious ones. However, that is not the alchemist fallacy. Many far more miraculous things have arisen than such a physical transformation. Rather, the alchemist fallacy is to think that, once such a process for producing gold is discovered, gold would retain its scarcity, and the discoverers would be rich beyond belief.

The modern analog to alchemy is the new economy, which indeed provides miraculous productivity growth along with a dazzling array of new goods and services. The phenomenal increases in computer power over the twentieth century, for example, were far more rapid than anything in the historical record. Many financial analysts apparently believed that a substantial part of the economic value of the innovations in new-economy firms would be captured by the innovators, and this in part drove the stock market boom of the dot.com firms and the NASDAQ market sector. The result was the rise in the value of computer-related firms from virtually nothing to over $4 trillion in early 2000.

The present paper investigates whether in fact investors in the 1990s once again succumbed to the alchemist fallacy. The United States economy did indeed benefit from rapid technological change over the last decade. Were innovators able to capture a significant fraction of the benefits from new technologies? Alternatively, were most of the benefits of improved productivity passed on in lower prices? These are among the topics studied below.

I. A Model of Appropriability and Schumpeterian Profits

A. Background

Endogenous growth theory, along with the theory of induced innovation, has developed important new approaches to understanding the role of innovation in economic growth. Joseph Schumpeter introduced modern approaches in his pathbreaking book, *The Theory of Economic*

Development.[2] The formal theory of induced innovation arose in the 1960s in an attempt to understand why technological change appears to have been largely labor saving.[3] More recently, theories of induced technological change were revived as the new growth theory, pioneered by Robert Lucas and Paul Romer.[4] This has blossomed into a major research field, with a wide variety of theories and applications.[5]

The underlying idea to be developed in this section is straightforward. Numerous individuals and firms in a modern economy are engaged in innovative activities designed to produce new and improved goods and services along with processes that reduce the cost of production. Some of these are formalized in legal ownership of intellectual property rights such as patents, copyrights, and trademarks, while others are no more than trade secrets or early-mover advantages. Some of the innovative activities produce extra-normal profits (called Schumpeterian profits), which are profits above those that would represent the normal return to investment and risk-taking.

In this study, we take a restrictive definition of Schumpeterian profits. These comprise only the profits that exceed the risk-adjusted return to innovative investments. In other words, any research and development (R&D) that yields a normal return on investment will lead to an increase in output or decrease in inputs but no increase in appropriately measured multifactor productivity (MFP).[6]

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[2] *Theorie der wirtschaftlichen Entwicklung*, variously dated as 1911 or 1912, available currently in translation published by Transaction Books, New Brunswick, N.J., 1983.

[3] See Richard Nelson, "The Simple Economics of Basic Scientific Research," *Journal of Political Economy*, vol. 67, 1959, pp. 297-306, and Kenneth Arrow, "Economic Welfare and the Allocation of Resources for Invention," in Richard Nelson, *The Rate and Direction of Inventive Activity*, Princeton University Press for National Bureau of Economic Research, 1962, pp. 609-625.

[4] See Robert E. Lucas, "On the Mechanics of Economic Development," *Journal of Monetary Economics,* January 1988, pp. 3-32, and Paul Romer, "Endogenous Technological Change," *Journal of Political Economy,* vol. 98, October 1990, No. 5, Part 2, pp. S71-S102.

[5] A comprehensive survey is provided in Philippe Aghion and Peter Howitt, *Endogenous Growth Theory,* MIT Press, Cambridge, Mass., 1997.

[6] Because of U.S. accounting conventions, R&D is treated as a current rather than a capital expense and will distort measures of MFP growth. Additionally, some R&D is devoted to new products, which may not be captured in price indexes; this factor will probably underestimate MFP growth.

Most of the innovations produce social value as well as private value. When copy machines replace scribes, or computers replace mechanical calculators, the social cost of producing a given amount of goods and services declines. It is well established that innovators do not generally capture the entire social value of inventive and innovational activity.[7]

Although there is scattered evidence that the degree of appropriability varies greatly across industries, there is little evidence on the size of the slice that goes to the originators of technological change and no evidence on the size of Schumpeterian profits for the entire economy.[8] Some industries like pharmaceuticals have high rates of profit and appear to capture a substantial fraction of the value of new products during (and sometimes after!) the patent lifetimes. Other industries, such as farming, have enjoyed very rapid productivity growth without a corresponding high profitability of farmers or farm-equipment manufacturers.

B. A Two-Period Model

We can formalize these issues as follows. The basic assumption is that there is a stream of innovations in an industry, which lead to a reduction in the cost of production, c_t, for firm or industry i (I suppress the notation that this refers to industry i where inessential). Some of the innovations are in the public domain, such as the availability of improved weather forecasts. These are inappropriable and are therefore passed on in lower costs and prices of goods or services. Other cost reductions are at least partially appropriable by the producers in the industry and are only partially passed on in price reductions. For those innovations whose cost reductions are partially appropriated, the producers or innovators will have temporary increases in profits, which are labeled Schumpeterian profits.

[7] There is a vast literature discussing the relationship between social and private returns to innovation. Among the most ambitious studies are Edwin Mansfield, "Social and Private Rates of Return from Industrial Innovations," *Quarterly Journal of Economics*, 1977, vol. 91, pp. 221-40 and Nathan Associates, *Net Rates of Return on Innovation*, Report to the National Science Foundation, 1978.

[8] William Baumol used estimates of investment and productivity growth to estimate that the overall spillover rate (one minus the appropriability rate) has been in the order of 80 percent. See William J. Baumol, *The Free-Market Innovation Machine,* Princeton University Press, Princeton, NJ, 2002, pp. 134-135.

The two-period version of this model will illustrate the basic points. Consider a perfectly competitive industry where the technology is constant returns to scale. The level of productivity is represented by A_t, and the cost of production is $C_t = kA_t$, where k is a constant. In period 0, the dominant technology is widely available and determines the market price. The dominant technology has cost C_0 and the good has a market price of $P_0 = C_0$.

A new innovation arrives in period 1 and lowers production cost to $C_1 < C_0$. Assume that the inventor can appropriate the fraction a of the cost savings from the innovation; a is the fundamental *appropriability ratio,* which will be estimated below. Then for small innovations, the inventor maximizes profit by setting the price at $P_1 = C_1 + a\,(C_0 - C_1)$. Figure 1 shows the initial competitive price, new cost, and new price under these assumptions. The shaded profit region is Schumpeterian profits. As is shown in Figure 1, the second-period price (P_1) lies between competitive cost of the old technology (C_0) and the new lower cost of the innovation (C_1). The extent to which P_1 is above the C_1 depends upon the appropriability ratio.

The inventor=s profits are equal to $(P_1 - C_1)X_1$, which can be approximated by $a\,(C_0 - C_1)X_0 = a\,[(C_0 - C_1)/C_0](P_0 X_0) = a\,(\Delta A_1/A_0)Q_0$, where $Q_t = P_t X_t$ is nominal output. In words, *the private value of the innovation to the innovator is approximately equal to the appropriability ratio times the rate of improvement in technology times the nominal value of output.*

C. A Multi-Period Model

To put this theory in a dynamic framework, we need to take into account the erosion of Schumpeterian profits over time. Schumpeterian profits decay because of such factors as the expiration or non-enforcement of patents, the ability of others to imitate or innovate around innovations, and the loss of first-mover advantages. I will model the erosion of Schumpeterian profits as a simple exponential process with decay rate λ per year. This implies that if an innovation was introduced θ years ago, the appropriation rate would be $ae^{-\lambda\theta}$ at the end of θ years. I assume that input costs are constant, so any cost reduction is caused by technological change. The rate of technological change is $h_t = -\dot{C}_t/C_t$.

I use the dot notation in $\dot{C}_t$ to designate a time derivative for continuous cost reduction; if changes are discontinuous, then we can think of this heuristically as a discrete change, which is described explicitly below. Using the framework just introduced, this implies that if there were only one innovation, which occurs in period $(t\text{-}\theta)$, current price would be:

$$(1) \qquad P_t = C_t - ae^{-\lambda\theta} (C_t - C_{t-\theta}).$$

Here, a is the first-period appropriability of innovations, while the appropriability θ periods after the innovation is $ae^{-\lambda\theta}$. If the stream of innovations is continuous, then current price would be determined by the past innovations and the extent to which Schumpeterian profits had eroded. Because an innovation θ periods ago yielded a cost improvement of $\dot{C}_{t-\theta}$, we can integrate all the cost improvements over time to obtain the complete version of (1):

$$(2) \qquad P_t = C_t - \int_0^{\infty} ae^{-\lambda\theta} \dot{C}_{t-\theta} \, d\theta.$$

The integral on the right hand side of (2) is the accumulated Schumpeterian profits, which I define as S_t:

$$(3) \qquad S_t = - \int_0^{\infty} ae^{-\lambda\theta} \dot{C}_{t-\theta} \, d\theta.$$

Note that since costs are falling over time, S_t is positive.

Finally, note that if the rate of productivity growth is constant at h^* per year, then (2) and (3) simplify to:

$$(4) \qquad (P_t - C_t)/C_t = \int_0^{\infty} - ae^{-\lambda\theta} [\dot{C}_{t-\theta}/C_t] \, d\theta = a\, h^*/(\lambda - h^*) .$$

We define $\mu_t = (P_t - C_t)/C_t$ as the *Schumpeterian profit margin.* The equilibrium Schumpeterian profit margin is equal to the appropriability ratio times a dynamic factor that equals the ratio of the rate of productivity growth divided by the difference between the rate of decay of Schumpeterian profits and the rate of productivity growth. The upper limit on the Schumpeterian profit margin is the appropriability factor, but this upper limit is reduced by deprecation.

Take the time derivative of the markup and use equations (2) and (3), which yields

$$\dot{\mu}_{t-\theta} C_t + \dot{C}_t \mu_t = d[\int_0^{\infty} - ae^{-\lambda\theta} \dot{C}_{t-\theta} d\theta]/dt = - \lambda S_t - a \dot{C}_t$$

Since $\dot{C}_t/C_t = - h_t$, this reduces to

$$(5) \qquad \dot{\mu}_t = (a + \mu_t) h_t - \lambda \mu_t$$

In steady state, where μ_t and h_t are constant at μ^* and h^*, this reduces to

$$(6) \qquad \mu^* = a h^*/(\lambda - h^*)$$

which is identical to equation (4). We can also derive equation (5) in difference form, which yields

$$(7) \qquad \mu_t = (1 - \lambda)\mu_{t-1} + a h_t + \mu_{t-1} h_t$$

The major coefficients of interest are λ, which is the rate of depreciation of Schumpeterian profits, and a, which is the Schumpeterian appropriation ratio.

Equations (6) and (7) are two alternative representations of the relationship between the Schumpeterian profit margin and the rate of technological progress. Equation (6) would be appropriate in circumstances where the industry was in "innovational steady state" – that is, where the rate of innovation was more or less constant. Equation (7) would be appropriate where the rate of technological change were changing, such as occurred in the new economy over the last decade.

D. A Multi-Period Calibrated Model

We can illustrate the model here using a calibrated model of innovation. For this purpose, I assume follow the model described in the last section. Invention (h_t) is assumed to be uncertain and follow a beta distribution with parameters (3, .3). This produces a median annual productivity growth of 0.3 percent per year and a standard deviation of around 10 percent per year. Multifactor productivity of the low-cost producer is equal to h_t. The other parameters are the appropriability factor = a = 0.2 and the depreciation rate = λ = 0.08 per year.

Figures 2 and 3 show a typical simulation of the system. Figure 2 shows the monopoly cost as the solid line as well as the market price with + marks. The market price is always higher than the monopoly price because of partial appropriability. Additionally, when there is little innovation (as between period 27 and 37), the price-cost margin tends to shrink as the Schumpeterian margin depreciates.

Figure 3 shows the Schumpeterian margin. This margin shoots up after a major invention, and then declines as Schumpeterian profits dissipate. From equation (6), the theoretical average Schumpeterian margin is

$$\mu^* = a h^*/(\lambda - h^*) = 0.2\ .018/(.08-.018\ ) = 5.8 \text{ percent},$$

whereas the average from the simulation shown in Figure 3 is 4.3 percent. The difference is due to the non-linearity of the margin equation.

Figure 4 compares the price trajectories of two simulations with the same underlying technological shocks but with different appropriability ratios, while Figure 5 shows the associated profit margins. For the high appropriability ratio of 0.5, the Schumpeterian margin is higher as actual price tends to remain above the monopoly cost while with the lower appropriability ratio of 0.1 there is little daylight between monopoly cost and price.

II. Empirical Estimate of Schumpeterian Profits

I now turn to empirical estimates of Schumpeterian profits. This is inherently difficult because of the many determinants of profits. One particularly tricky issue is the business cycle, which causes consistent comovements between productivity and profits. A second problem is that measures of productivity growth are by their nature indirect, derived as a residual from the difference between output and input growth. A final problem is that Schumpeterian profits are but one source of profits and must be separated from the return to capital, rewards for risk-bearing, monopoly profits from non-technological sources such as entry limitations, natural-resource rents, and financial finagling.

Note that the theory applies to all innovations, domestic and foreign. In practice, the technique used here can only estimate appropriability of productivity growth in the United States on innovational profits in the United States as measured in domestic product and income. Since there are both spill-outs to the international economy from domestic innovation as well as spill-ins to the U.S. economy from foreign innovations, our estimates are likely to be distorted. The direction of the distortion is difficult to determine, however, because the procedure is likely to overestimate the appropriability of domestic innovations (because some productivity impacts occur abroad) and underestimate domestic appropriability because of foreign innovations (which affect productivity but will not affect domestic profits).

The empirical estimates use two different approaches. The first section provides the macroeconomic estimates; these do not provide especially sharp results, probably for the reasons just discussed. The second section uses a panel of industry data; these are better determined, but the data quality is not as satisfactory.

A. Macroeconomic Estimates

To determine the appropriability of innovation, I examine annual data on multifactor productivity for the non-farm business section. I limit the analysis to the nonfarm sector because land values are such a large fraction of total capital in that sector. The annual data are prepared by the Bureau of Labor Statistics (BLS) for their calculations of multifactor productivity. The analysis here uses a margin defined as total property income divided by total costs (μ_1). This margin is available from the BLS data and has relatively few conceptual difficulties.[9]

[9] All data are available at http://www.bls.gov/web/prod3.supp.toc.htm.

The results for the macroeconomic data are fragile and inconsistent across different specifications. I will show two examples that give the flavor of the results. One specification begins with the dynamic one in equation (7) and solves it for the *recursive approach*. For this purpose, I estimate the margin as a function of the ten-year geometric average of productivity growth; that period is assumed sufficiently long to remove cyclical properties but short enough to leave a sufficient number of degrees of freedom. More precisely, the recursive approach solves (7) to obtain:

$$(8) \qquad \mu_t = \alpha \sum_{j=0}^{T-1} \{ h_{t-j} [1-\lambda]^j \} + (1-\lambda)^T \mu_{t-T} + u_t$$

There is no consensus on the appropriate depreciation rate for R&D, with estimates ranging from 10 to 25 percent per year. The calculations in Table 1 assume a depreciation rate of 20 percent per year, which is consistent with data from patent renewals.[10] It has not been possible with the macroeconomic data to estimate the appropriability ratio and the deprecation rate jointly. The estimate for equation (8) is shown as the first line in Table 1. These estimates are conditional on a value of depreciation of $\lambda = 0.2$. This equation yields an estimate of $a = 0.083$, with a standard error of 0.184.

A second approach is the *equilibrium model*. For this approach, I assume that the margin is determined from the long-run equilibrium in equation (6). Taking the Taylor expansion of equation (6), we can rewrite it as

$$(9) \qquad \mu_t = \gamma_0 + \gamma_1 h_t + \varepsilon_t$$

With some calculations, we can derive that $\alpha = \gamma_1 (\lambda - h^*)^2 / \lambda$, where γ_1 is the regression coefficient from (9).

[10] See Ariel Pakes and Margaret Simpson, "Patent Renewal Data," *Brookings Papers on Economic Activity, Microeconomics*, 1989, pp. 331-410 and the references therein. Estimates of the depreciation rate for patent renewals are higher than the numbers in the literature on the returns to research and development (which cluster around 15 percent per year). However, the latter generally refer to social rather than private depreciation, and the private rate would generally exceed the social rate due to erosion of market position of the innovator. (See Bronwyn H. Hall, "Industrial Research during the 1980s: Did the Rate of Return Fall?" *Brookings Papers on Economic Activity, Microeconomics*, 1993, pp. 289-343.)

Table 1 provides the results of the equilibrium model in (9). The estimates of the appropriability factor are around 5 percent, which is consistent with the dynamic version. However, the results are sensitive to alternative specifications. For example, if the productivity term is lagged one year, the coefficient becomes negative. If an output term is added, to reflect cyclical productivity growth, then the coefficient becomes very poorly determined.

B. Empirical Estimates Using Industry Data

A second set of estimates uses industry data. Two potential approaches are company data and national accounts data. In principle, it would be desirable to use narrowly targeted company data so that the large differences in profits and technological performance could be separately identified. However, firm data are generally unavailable because of the lack of reliable real output and productivity indexes by firm. Equally serious is that firm data are generally limited to large firms listed on stock exchanges, and these data suffer from potentially large selection bias.

The alternative, which is followed here, is to use national accounts data by industry; this approach allows estimates of cost, price, profits, capital stocks, margins, and productivity. For this purpose, BEA developed output, price, labor inputs, capital stocks, and profits after taxes for 65 detailed SIC industries (these data are no longer published and have been replaced by data using NAICS classification). Together with Alexandra Miltner, I have prepared consistent data for the 1948-2001 period. Of the 65 industries, I use 27 that have reasonably good price deflators and therefore relatively reliable measures of real output and productivity. For these estimates, there are 27 panels and a total of 1154 observations.

For these estimates, the productivity concept is the growth in total factor productivity measured as the difference between the growth in real output and the growth of an index of labor and capital inputs. There are two different margin concepts. The first, which is similar to that for the aggregate data, uses the gross property margin; this concept equals all property type income (profits, proprietors income, rents, interest, and capital consumption), which in turn is equal to value added less indirect business taxes less total compensation. The second margin concept is the gross rate of return on capital. This is equal to gross all property type income divided by the current value of the replacement cost of capital.

The difference between the two concepts is essentially the difference between nominal output and nominal capital value.

Table 2 shows the basic results for the industry data. I estimate the coefficients using fixed industry effects and fixed time effects. The regression includes also a term in the current growth of real output to capture (reversible) cyclical effects. The estimates were performed using EViews 5.0.

The results are better determined than for the aggregated data, but they are inconsistent between the two profit concepts. The property margin shows the most precisely estimated values. Both sets of estimates are reasonably well determined, and they are also reasonably robust to alternative specifications. The industry estimates suggest an appropriability ratio higher than those from the aggregate data, with a central estimate around 10 percent for a depreciation rate of 20 percent.

C. Estimates of Total Appropriability

Combining the macroeconomic and industry estimates, we can get an order-of-magnitude estimate of the total fraction of the gains from innovation that are captured by innovators. While estimates from the different sources are inconsistent, the best guess would be for an initial appropriability ratio of 10 percent at a depreciation rate of 20 percent per year.

This estimate of appropriability applies only to the first year of an innovation. After the first year, the appropriability depreciates over time because of imitation and loss of market power. At a depreciation rate of 20 percent per year, the estimated 10 percent appropriability declines to 1.6 percent after a decade and 0.3 after two decades.

The overall appropriability of innovation is defined as the fraction of the present value of an innovation that is captured by the innovator. It is determined using both the appropriability coefficient and the depreciation rate. The central estimates of these two parameters are 0.10 and 0.20. If we combine these estimates with a real growth rate of the economy of 3 percent per year and a discount rate on Schumpeterian profits of 10 percent per year, this implies that 3.7 percent of the total present value of social returns to innovation are captured by innovators.

III. Innovation, the New Economy, and the Alchemist Fallacy

A. The New Economy in Schumpeterian Perspective

An interesting application of Schumpeterian profit theory is to the "new economy" of the 1990s. The rise and fall of the stock values of new-economy firms is well known. At its peak, most analysts who believed that stock market valuations of new-economy firms were anywhere-near realistic held that (a) these firms were highly innovative and (b) innovative firms could capture a substantial part of the value of their innovations. To put this in the language of this study, if the rapid growth in innovation produced an accompanying rapid growth in Schumpeterian profits, then the present value of future profits would rise sharply.

To put this quantitatively, consider the following example: The new economy amounts to 5 percent of nominal output. Up to an initial period (say, 1995), productivity is perceived to be growing at the same rate as in other sectors. Then, a rapid acceleration of productivity growth occurs. In the new world, assume that costless multifactor productivity growth accelerates by 10 percent per year. Assuming total output is $10 trillion in the initial year, the new economy would be adding about $50 billion per year per year in social surplus in the initial year. If the new entrepreneurs could capture 90 percent of the new-economy surplus in Schumpeterian profits with low depreciation, then with other plausible parameters, the *increase* in value of new-economy firms would be $4.4 trillion. This is close to the increase in value of new-economy firms from 1995 to 2000.

B. Appropriability in the New Economy

Does this story fit reality? Or, was the alchemist fallacy at work here? There is little doubt that the new economy was highly innovative, with extremely rapid productivity growth. This section attempts to estimate whether the appropriability of new-economy innovations was unusually high. For this purpose, I define the new economy as involving acquisition, processing and transformation, and distribution of information. The major new-economy sectors are Industrial machinery and equipment (SIC 35), Electronic and other electric equipment (SIC 36), Telephone and telegraph (SIC 48), and Business services (SIC 73). I use the same database here as in the industrial estimates above.

Table 3 shows the estimates for two different groupings of new-economy industries. These use only the margin estimates *(μ_1)* because the rate of return on capital is misleading given the high share of intangible investments in these industries. The results for the four industries indicate an appropriability ratio for the new economy of 6 percent with a depreciation rate of 20 percent. The results are consistent with but slightly lower than the estimates in Table 1. However, if we include only the computer industries (SIC 35 and 36), then the appropriability ratio is actually negative, reflecting the declining profits in the period when productivity growth rose during the 1990s. Neither set of coefficients is well determined. The conclusion is that appropriability in the new economy was not significantly different from the old economy.

To return to our example of new-economy stocks, let us use numbers that are more realistic than the 90 percent appropriability rate. If the new-economy entrepreneurs could capture 6 percent of the social gains – which is a good guess based on our estimates – then under the assumptions above the increase in the market value of the excess profits from the productivity acceleration would be $300 billion rather than to $4.4 trillion. The $300 billion would be a better estimate of the increased value of these firms today.

Does this low a number make economic sense? We might be skeptical of high Schumpeterian profits in the new economy because of the nature of the industry. With a few exceptions, entry and exit are relatively easy; the rapidity of the entry and easy demise of new-economy firms indicates not only that bright ideas were easily funded but also, alas, that imitators were quick to follow. One way that the high entry and exit will affect Schumpeterian profits is through the depreciation rate, which is likely to be very high in new-economy sectors. Etoys.com sounded like a great idea for toys; but Toys-R-Us had more expertise and toys and could easily and quickly adopt the bright ideas of the first mover. In reality, both are bankrupt today. While we have incomplete information on the aggregate profits of new-economy firms, it appears that at the peak of the cycle in 2000, profits in this industry were actually negative.[11]

[11] The Bureau of Economic Analysis publishes corporate profits by industry for three new-economy industries using the new industrial classification system (NAIQS): Computer and electronic products, Electrical equipment, appliances, and components, and Information. Profits for these industries was $-8 billion in 2000 and has been negative for every year thereafter. (Data are from Table 6.16D in the NIPA tables at www.bea.gov.)

Another reason to doubt the presence of large Schumpeterian profits is that the information revolution concerns information, which is intrinsically hard to appropriate. The economic nature of information is that it is expensive to produce and inexpensive to reproduce. Indeed, with the Internet, it is often essentially free to reproduce and distribute vast amounts of information. The low costs of imitation, transmission, and distribution of information technologies are likely to erode the value of property rights in intellectual property and reduce the durability of Schumpeterian profits in the new economy. An illustrative case is the appropriability of the value of knowledge embedded in encyclopedias. To imitate the *Encyclopedia Britannica* two decades ago would have required a massive investment in recruiting of scholars and editors along with a major publishing effort. Today, an online or CD encyclopedia is extremely inexpensive to produce and distribute, and some are free to consumers, such as Microsoft's online *Encarta*. Indeed, the Internet is itself a gigantic free encyclopedia.

C. The Greenspan Effect

In this section, we consider the implications of this analysis for the stock market and for the "Greenspan effect." In the late 1990s, productivity and the economy were growing rapidly, and some economists wondered whether there was a linkage through the stock market. Just such an effect was suggested by Federal Reserve Chairman Alan Greenspan:

> Productivity-driven supply growth has, by raising long-term profit expectations, engendered a huge gain in equity prices. Through the so-called "wealth effect," these gains have tended to foster increases in aggregate demand beyond the increases in supply….
>
> [In] recent years, largely as a result of the appreciating values of ownership claims on the capital stock, themselves a consequence, at least in part, of accelerating productivity, the net worth of households has expanded dramatically, relative to income. This has spurred private consumption to rise even faster than the incomes engendered by the productivity-driven rise in output growth.[12]

I define the *Greenspan effect* as the impact of rising productivity on aggregate demand through the wealth effect on consumption. Greenspan

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[12] Alan Greenspan, "Technology and the economy," Before the Economic Club of New York, New York, New York, January 13, 2000 at http://www.federalreserve.gov/boarddocs/speeches/2000/200001132.htm.

suggested not only that the impact is positive, but also that it is larger than the impact on aggregate supply.

The estimates provided here allow an estimate of the size of the Greenspan effect operating through private consumption. For this purpose, assume that all of output is produced in publicly owned corporations and that all productivity growth is driven by domestic innovation. From these, we deduce following from the model in section I. The current value of Schumpeterian profits as a fraction of corporate output is V = $ah^*/(\lambda - h^*)$, and the value of equities is the discounted value of that. Suppose that economy-wide productivity rises permanently by Δh^* percent per year. Further, assume that the marginal propensity to consume out of wealth is w. Using the empirical estimates from section II (a = .10 with λ = 0.2) and these assumptions, the ratio of the present value of Schumpeterian profits to corporate output is 6.9 percent when productivity growth is 1 percent per year, while that ratio is 15.4 percent with productivity growth of 2 percent per year. Using the value of w of 0.04, the increase in consumption from an unanticipated increase in productivity growth by 1 percentage point is .04 x (.154 - .069) = 0.34 percent of total output.[13]

Hence for the estimated value of the parameters, an unanticipated 1 percent increase in multifactor productivity that is driven entirely by appropriable innovation will lead in the first year to a 1 percent increase in potential output and a 0.34 percentage point increase in consumption. This calculation suggests that the Greenspan effect on aggregate demand through consumption is about one-third of the effect on potential output, and that this impact of productivity growth through the Greenspan effect is not inflationary.

IV. Conclusion on Alchemy and Appropriability

The present study develops a technique for estimating the size of Schumpeterian profits in a market economy. It shows that innovational

[13] The calculation becomes more complicated if we correct for the fact that the corporate output is only about 60 percent of total GDP and that only part of the return to capital is earned by public corporations. If all MFP growth in confined to public corporations, then the numbers in the text will all be scaled down by the ratio of the output of public corporations to GDP but the ratio, 0.24, will be unchanged. If some of MFP growth occurs outside of public corporations, then the ratio would be smaller to the extent that business owners are constrained from consuming according to the underlying consumption model.

profits depend upon the appropriability of innovations as well as the rate of depreciation of profits from the innovations. Using both aggregate and industry data for the United States, I estimate that innovators were able to capture about 4 percent of the total social surplus from innovation. This number results from a low rate of initial appropriability (estimated to be around 10 percent) along with a high rate of depreciation of Schumpeterian profits (judged to be around 20 percent per year). In terms of the rate of profit on capital, the rate of profit on the replacement cost of capital over the 1948-2001 period is estimated to be 0.27 percent per year.

One reaction to these numbers is that the rate of Schumpeterian profits is implausibly low given the enormous innovativeness of the American economy. Another reaction is that it clears up at least part of a puzzle about the profitability of American capitalism. Some observers have wondered why the rate of profit on corporate capital is so low. Indeed, over the last four decades in which we have careful measurement, the rate of profit after tax on nonfinancial corporations averaged 5.9 percent per year, which was very close to the cost of capital over that period. How could the rate of profit be so low, it might be asked, given that the denominator omits several important assets (such as land and intangible investments) and the numerator includes important sources of profits (such as monopoly power and Schumpeterian profits)? At least part of this puzzle is resolved here by the finding that only 27 basis points of the rate of return to capital were due to Schumpeterian profits.

Another point, emphasized by William Baumol, is that a low but positive appropriability ratio is critical for the success of innovative capitalism. Given the enormous social returns to innovation, firms and entrepreneurs require but a low appropriability ratio to provide powerful incentives for substantial efforts in innovative activity. Were appropriability zero and there no private returns to innovative activity, innovation could well be absent, as it has been for much of human history. On the other hand, were appropriability extremely high, then Schumpeterian profits would take a large share of output, prices would be inefficiently high, and political pressures might well lead to measures to eviscerate intellectual property rights. While not suggesting that the dial on appropriability is set exactly correctly in current intellectual property laws, Baumol's basic insight – that the free-market innovation machine generates remarkable productivity growth without excessive returns to entrepreneurs – is reinforced by the current study.[14]

The low appropriability of innovation should caution investors about committing the alchemist fallacy. Alchemy was an ancient art devoted to discovering a miraculous substance that would transmute common metals into gold. In the late 1990s, some believed that such a virtual substance had been found in the electronic world. But the laws of economics teach us that were anyone to find such a miraculous substance, its value would quickly fall as gold became as common and cheap as sand, optical fiber, and silicon chips. In retrospect, the laws of economics look like a safer bet than the lure of alchemy.

[14] William J. Baumol, *The Free-Market Innovation Machine,* Princeton University Press, Princeton, NJ, 2002.

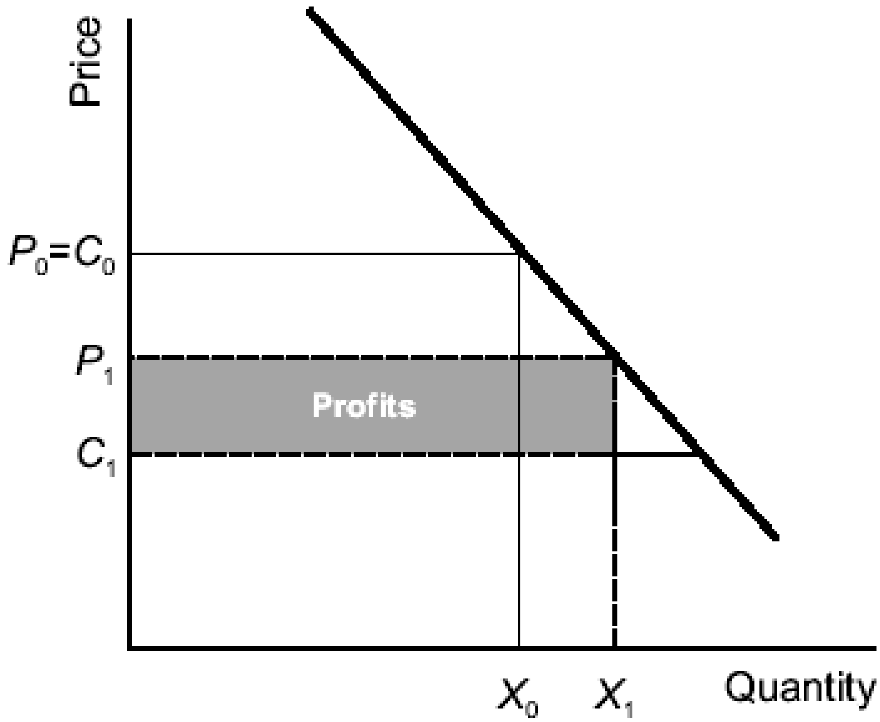

Figure 1. Technological Change and Schumpeterian Profits

The shaded region shows the Schumpeterian profits, while social surplus is the quadrilateral bounded by the $P_0 = C_0$ line, the demand curve, the C_1 line and the vertical axis. The ratio of Schumpeterian profits to social gains is determined by the appropriability ratio.

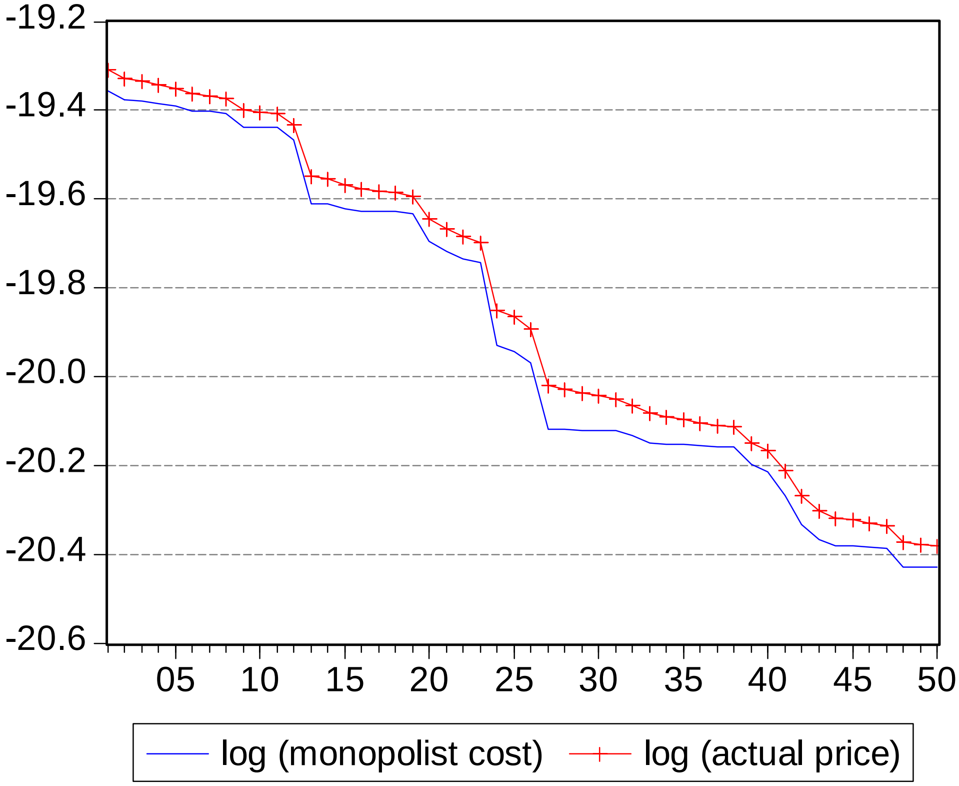

Figure 2. Simulation of cost and price in Schumpeterian model (50 periods)

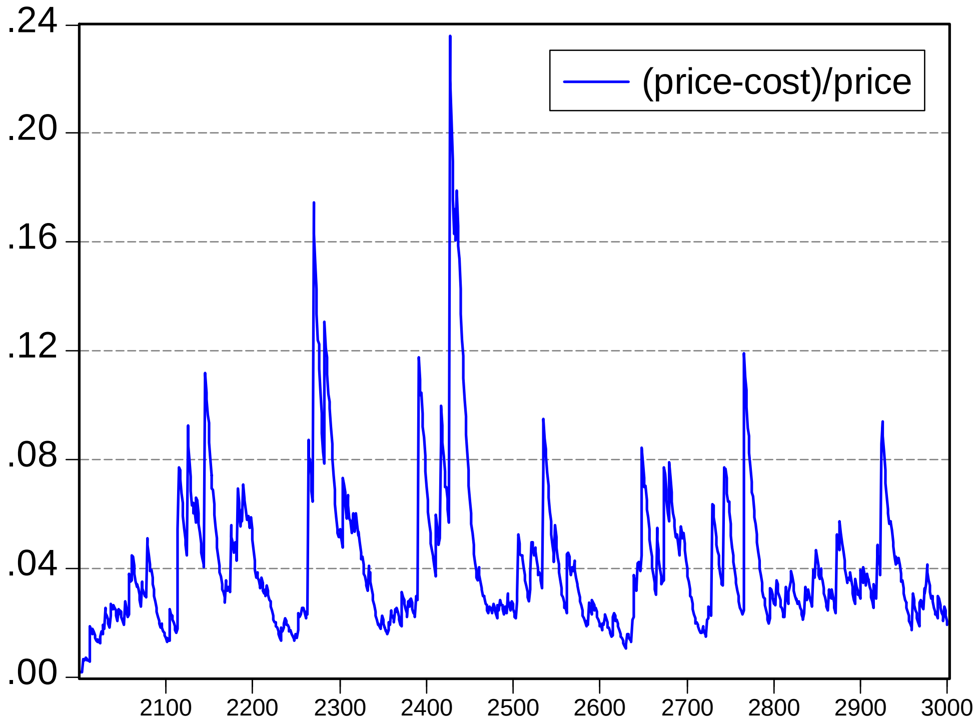

Figure 3. Simulation Schumpeterian profit margin (1000 periods)

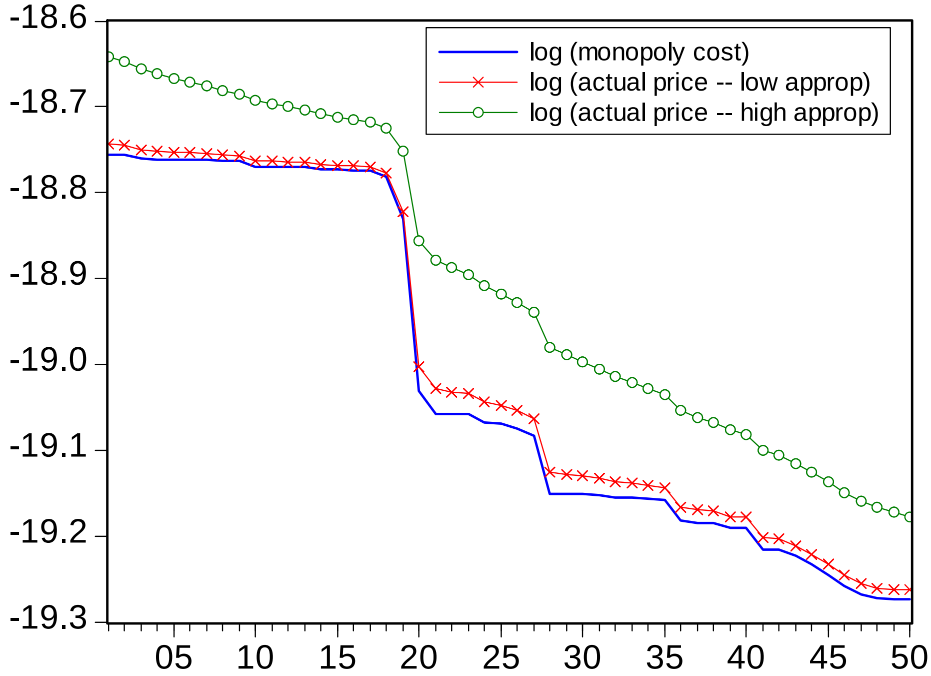

Figure 4. Price trajectories under low and high appropriability (50 periods)

(Upper line (o) has appropriability factor of 0.5 while lower line (x) has appropriability factor of 0.1)

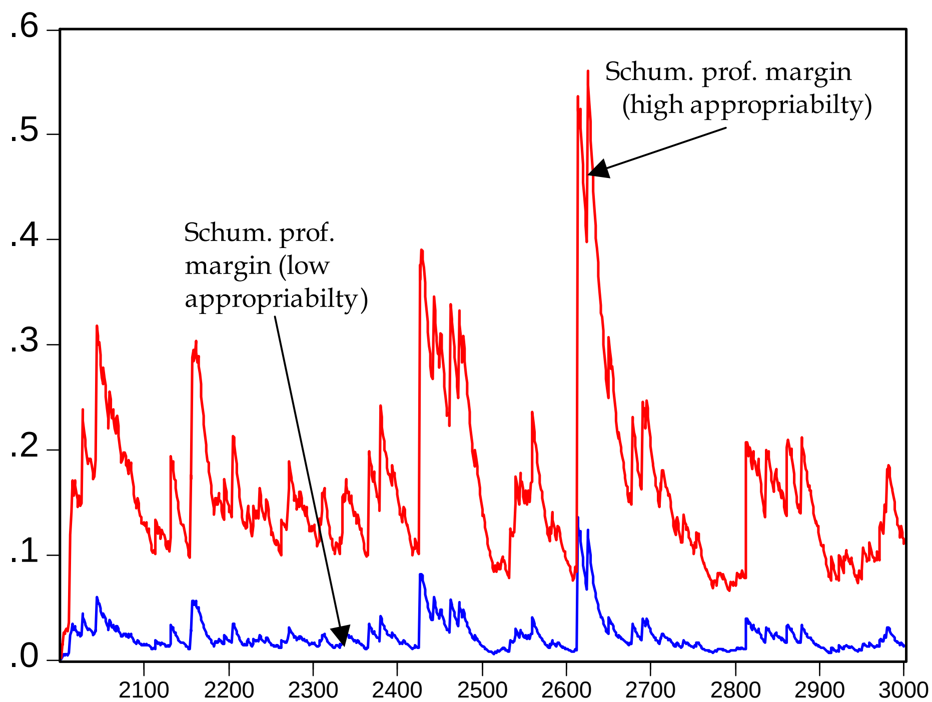

Figure 5. Schumpeterian margins with high and low appropriability (1000 periods)

Sector and method		Regression Coefficients: Coeff-icient	Regression Coefficients: Standard error of coefficient	Appropriability Ratio [a]: Coeff-icient	Appropriability Ratio [a]: Standard error		Equilibrium Share of Schumpeterian Profits [Percent of total output]
Recursive							
	Level + AR	0.084	0.184	8.4%	18.4%		0.59%
Equilibrium							
Annual	Level +ARMA1	0.331	0.080	5.9%	1.4%	[b]	0.41%
Decadal	Level +ARMA1	0.262	0.063	4.6%	1.1%	[b]	0.33%

[a] All estimates assume the depreciation rate is 20 percent per year (exponential).
[b] These standard errors take the standard errors and scale them proportionally for the ratio of the appropriability coefficient to the regression coefficient.

Table 1. Results for the aggregate non-farm business sector, 1947-2004

Margin and depreciation rate	Regression Coefficients (appropriability ratio)	
	Coeff-icient	Standard error of coefficient
Rate of return on capital		
Depreciation = 0.1	0.051	0.025
Depreciation = 0.2	0.029	0.036
Property margin		
Depreciation = 0.1	0.128	0.017
Depreciation = 0.2	0.130	0.024

Table 2. Appropriability estimates for major industry, 1948-2001
Estimates show appropriability coefficient using recursive equation (8) with 10-year lag. Estimates differ conditional on depreciation rate and on concept of margin used.

Sectors and depreciation rate	Regression Coefficients (appropriability ratio)	
	Coefficient	Standard error of coefficient
All New Economy Industries		
Depreciation = 0.1	0.027	0.045
Depreciation = 0.2	0.061	0.061
Computer Industries		
Depreciation = 0.1	-0.326	0.121
Depreciation = 0.2	-0.276	0.191

Note: All new-economy industries include Industrial machinery and equipment (SIC 35), Electronic and other electric equipment (SIC 36), Telephone and telegraph (SIC 48), and Business services (SIC 73). Computer industries are only SIC 35 and 36.

Table 3. Appropriability Estimates for "New Economy"
Estimates show appropriability for two different groups of new-economy sectors

Appendix A. Industry Data

The following are the universe of industries for which output and productivity data are available. Industries with asterisks are those that are thought sufficiently reliable to include in the regression analyses. The output, price, and value data as well as the derivation of the data are available on the author's web site at http://www.econ.yale.edu/~nordhaus/homepage/recent_stuff.html .

Gross Domestic Product (income side)
Private industries
  Agriculture, forestry, and fishing
    Farms
    Agricultural services, forestry, and fishing
  Mining
    Metal mining*
    Coal mining
    Oil and gas extraction
    Nonmetallic minerals, except fuels*
  Construction
  Manufacturing
    Durable goods
      Lumber and wood products*
      Furniture and fixtures*
      Stone, clay, and glass products*
      Primary metal industries*
      Fabricated metal products*
      Industrial machinery and equipment*
      Electronic and other electric equipment*
      Motor vehicles and equipment*
      Other transportation equipment*
      Instruments and related products*
      Miscellaneous manufacturing industries
    Nondurable goods
      Food and kindred products*
      Tobacco products
      Textile mill products*
      Apparel and other textile products*
      Paper and allied products*
      Printing and publishing*
      Chemicals and allied products*
      Petroleum and coal products
      Rubber and miscellaneous plastics products*
      Leather and leather products*
  Transportation and public utilities
    Transportation
      Railroad transportation*

Local and interurban passenger transit
Trucking and warehousing*
Water transportation
Transportation by air*
Pipelines, except natural gas
Transportation services
Communications
Telephone and telegraph*
Radio and television*
Electric, gas, and sanitary services*
Wholesale trade
Retail trade
Finance, insurance, and real estate
Depository institutions
Nondepository institutions
Security and commodity brokers
Insurance carriers
Insurance agents, brokers, and service
Real estate
Nonfarm housing services
Other real estate
Holding and other investment offices
Services
Hotels and other lodging places*
Personal services
Business services
Software
Other
Auto repair, services, and parking
Miscellaneous repair services
Motion pictures
Amusement and recreation services
Legal services
Educational services
Social services
Membership organizations
Other services
Private households
Statistical discrepancy
Government
Federal
General government
Government enterprises
State and local
General government
Government enterprises