Oil Crisis, Energy-Saving Technological Change and the Stock Market Crash of 1973-74[*]

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Abstract

The market value of U.S. corporations was nearly halved following the Oil Crisis of October 1973. Real energy prices more than doubled by the end of the decade, increasing energy costs and spurring innovation in energy-saving technologies by corporations. This paper uses a neo-classical growth model to quantify the impact of the increase in energy prices on the market value of U.S. corporations. In the model, corporations adopt energy-saving technologies as a response to the energy price shock and the price of installed capital falls due to investment irreversibility. The model calibrated to match the subsequent decline in energy consumption in the U.S. generates a 25% decline in market valuation; accounting for more than half of what is observed in the data.

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1 Introduction

The market value of U.S. corporations, relative to the replacement cost of their tangible assets, was nearly *halved* during 1973-74 (See Figure 1). This ratio, also known as the Tobin's (average) q, averaged 1.06 over the 1962-72 period, fell sharply during 1973-74, and stagnated for the following decade. Over 1974-1984, Tobin's q for U.S. corporations averaged only 0.56, 49% less relative to the decade prior to 1973. This decline in market valuations was highly persistent as they recovered to their pre-1973 levels only by the late 90's.

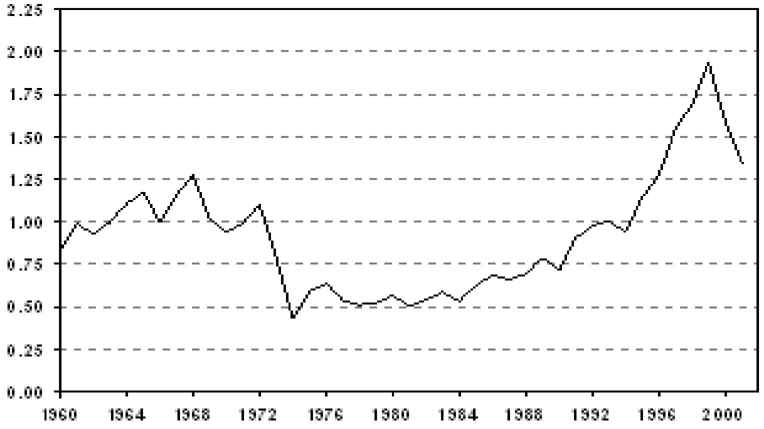

Figure 1: Tobin's average q: Market value relative to replacement value of tangible assets of U.S. corporations

This abrupt decline in corporate market valuations coincides exactly with the oil crisis initiated by the OPEC embargo announced in early October of 1973. The largest drop in market values occurred in the 4th quarter of 1973 and throughout 1974 (See Figure 2).

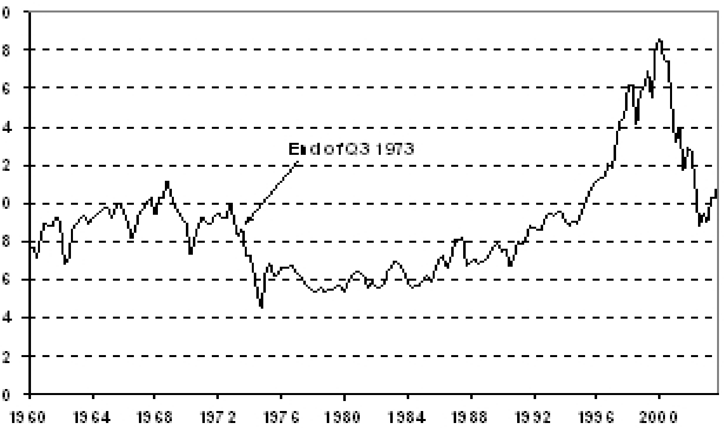

Figure 2: Market Value of U.S. corporations relative to GDP

The oil crisis translated into a 38% percent increase in real energy prices over 1973-74. Energy prices continued to rise for the rest of the decade, especially during 1979-80 due to the events in Iran (See Figure 3). By 1981, real energy prices were 2.2 times higher than what they were in 1972. Since 1982, energy prices have been declining. However they have yet to come back to their pre-1973 levels after 30 years.

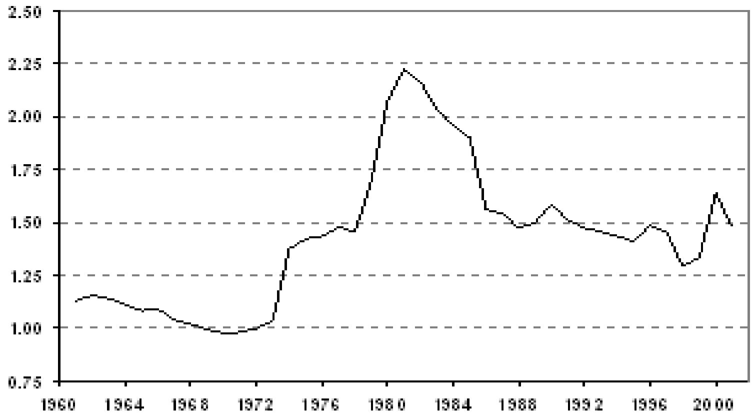

Figure 3: Energy prices relative to GDP deflator (1972 = 1)

The links between the increase in energy prices and the fall in market valuations seem intuitive and straightforward: First, the sharp and persistent increase in energy costs must have squeezed both current and expected future dividends causing the market value of us corporations to go down. Second, as the increase in energy costs was highly persistent, corporations started adopting and investing in new technologies that were more energy-efficient. This spur in energy-saving technologies resulted in capital obsolescence for the old energy-inefficient technologies driving their value down (cf. Baily [3]). Although these links are intuitive and the timing of the two events is suggestive, the energy explanation has had difficulties both empirically and theoretically and has led many authors to entertain other explanations for the stock market crash of 1973-74.

The main empirical criticism regarding the energy explanation is that there is not a high enough correlation between the drop in market values and the pre-1973 cost share of energy for corporations (cf. Wei [45] and Greenwood & Jovanovic [14]). For the manufacturing sectors at the level of 2-digit SIC code, the correlation is only 0.09. On the theoretical side it has been difficult to construct models where energy prices have a quantitatively significant impact on corporate market values primarily because the share of energy in total costs of businesses is small. In particular, Wei [45] uses a putty-clay model to find that energy increases can account for only 2% of the decline in market valuation.

The first criticism would be especially strong if rising energy costs were the main channel through which energy affected market values and Tobin's q. However, this cannot be the case. In fact there is no reason to expect a drop in Tobin's q due to an increase in energy prices as long as the price of installed capital does not deviate from potential replacements. If capital is homogeneous (i.e. the replacement capital is exactly the same as installed capital in terms of energy efficiency and other respects), then Tobin's q which measures market value (or value of installed capital) relative to replacement value will not be altered regardless of the cost share of energy. In this respect, the introduction of new energy-efficient technologies and the obsolescence of old technologies appears to be a better explanation for the drop in Tobin's q. We would expect to see a higher drop in Tobin's q in an industry that can reduce energy costs through the adoption of new technologies even when its initial cost share of energy is smaller than another industry which cannot adopt new technologies. For manufacturing industries at the 2-digit SIC code level, the correlation between the drop in market value and the drop in energy costs following the energy crisis is 0.41. The latter figure is much higher than the correlation of the drop in market value with the initial cost share of energy.

On regards to the second criticism, we should first note that the energy costs in the business sector is not that small, it amounted to almost 7.5-8% of the value of output produced by the business sector prior to the 73 crisis instead of the 4% cited by Wei [45]. The relevant price index to look at is the energy consumption and not production prices as businesses are consumers of energy. Second, even though the putty-clay model is intended to capture price induced savings in energy by allowing substitution in new vintages of capital, it counterfactually predicts that real energy-output ratio starts going up as energy prices start to decline in the 80's and 90's. As shown in Figure 4, real energy use (as a share of output) declined monotonically after 1973-74 even when energy prices were going down in the 80's. This fact is consistent with a technology that is characterized by increasingly lower energy requirements per unit of production (i.e. energy-saving technological change) and not consistent with a putty-clay model.

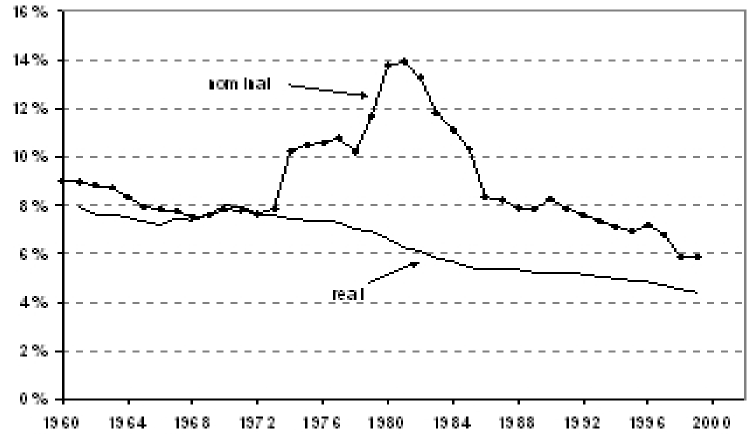

Figure 4: Energy expenditure (nominal) and energy use (real) of the business sector as a share of business GDP

In this paper we use neo-classical growth theory to address whether and if so how much of the decline in corporate market valuations can be accounted for by the observed changes in energy prices. The model is a dynamic general equilibrium model with technology-specific capital and investment irreversibility. These assumptions are standard in the literature (cf. Sargent [39], Dixit and Pyndick [9]), and allow for Tobin's q to fall below 1, as in the data. In the model economy, firms adopt energy-saving technologies as a response to the energy price shock and the price of installed capital falls due to investment irreversibility. Firms do not adopt these energy-saving technologies prior to the energy shock since there is a minimum investment requirement similar to Boldrin & Levine [4] before the firms can operate these new technologies. With low energy prices, firms forego this cost. However, with sharp increases in energy prices it pays for them to do so. We calibrate the parameters of the model to match certain features of the U.S. economy, in particular we set the energy-efficiency of the new technologies to match the decline in real energy output ratios. Given this feature, our model suggests energy prices can account for at least half of the drop in Tobin's q, and partially for its stagnation throughout the 70's and 80's.

Other explanations put forward for the stock market crash of 1973-74 are the IT revolution (cf. Greenwood & Jovanovic [14])and investment subsidies provided by the government to businesses (cf. McGrattan & Prescott [29]). The IT explanation is similar to our explanation in spirit, whereby the innovation of information technologies drive down the price of installed capital. Peralta-Alva [33] uses a neoclassical growth model with capital accumulation to test this idea and finds that the quality of new technologies that will generate the observed drop in Tobin's q would also generate a two-fold increase in investment, sharply in contrast with the data. McGrattan & Prescott [29] argue that the investment subsidies drive a wedge between the price of installed capital and replacement capital and can account for one third of the decline in market valuations observed in the 70's. Our model is not inconsistent with this explanation, since part of the reason for investment subsidies was to encourage firms to adopt new energy-efficient technologies. We nevertheless abstract from subsidies in our model, and concentrate on the effects of the oil crisis and energy-saving technological change in isolation from the government response.

Section 2 offers evidence on innovation of energy-saving technologies by firms after the oil crisis. Section 3 lays out the model. Section 4 discusses calibration, computation and findings. Section 5 concludes.

2 Innovation in Energy-Saving Technologies after 1974

The fundamental assumption in our analysis is that capital embodies a particular technology. Such an assumption is familiar from Robert M. Solow (1960) and fits particularly well with inventions that transform the whole economy. In our model, the introduction of a new type of capital gives birth to a new aggregate production function characterized by its energy-saving properties. In what follows, we provide empirical support for this hypothesis. As is well-known in the environmental economics literature, energy-saving technologies transformed U.S. production methods. In particular, the U.S. energy intensity - the ratio of BTUS of energy use to output - halved over the 1974-2000 period. First, we give some examples of the energy-saving technologies behind the decline in the U.S. energy intensity. Then, we provide additional evidence that suggests energy-saving methods were developed and adopted as a result of the energy crisis of 1973-74.

One of the most important changes in the manufacturing sector during the 1975-1995 period was the increased use of Advanced Manufacturing Technologies. Examples of this include computer aided design and manufacturing, numerically-controlled machines, and information networks. These improvements constitute a form of embodied technological change. It is new capital, including both hardware and software, that incorporates the advancements in technology. Doms and Dunne [11] use establishment-level data to determine changes in energy and electricity intensity arising from differences in plant characterisitics and energy prices. Their two main findings are first, plants that utilize higher numbers of advanced technologies are less energy intensive and rely more on electricity as fuel source. In particular, plants based on advanced manufacturing technologies consume less energy per unit of output, but consume a higher proportion of electricity. Second, plants constructed during the period of high energy prices, 1973-1983, are generally more energy efficient than plants built during other periods. Hence, the adoption of advanced manufacturing technologies is key to understanding both; the steady decline in energy intensity and the increase in electricity's share of total energy consumption that started around 1974.

Schiper [40] documents that most of the decline in energy intensity of the us economy can be attributed to improved energy efficency and not to the level and structure of sectoral activity[1]. As we discussed before, one important reason why the manufacturing sector improved its energy efficency was the introduction of advanced manufacturing technologies. Another development that lowered the energy intensity of all sectors was the introduction of energy-efficient buildings. U.S. residential and commercial buildings consume 40% of all U.S. energy and are therefore key to understand the trends in energy intensity. Rosenfeld (1990) finds that most of the efficiency gains in the heating and cooling of buildings took place during the period of high energy prices, 1973-1983. During those years, technological improvements in the heating, lighting and cooling systems[2] allowed for a decrease of 1.2 million barrels of oil per day (an amount equal to two-thirds of the daily output of the Alaskan pipeline) despite the fact that 20 million new homes were built, and commercial floor space increased by 40 percent. A sector that also experienced dramatic energy-saving changes after 1974 was the plastics industry. This industry is interesting because its major technological leap in energy-saving, and in overall productivity, involved major restructuring of the plants producing plastics. Joyce [23] documents that the Union Carbide

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[1] One important example of changes in the structure of sectoral activity is the decline of manufacturing - an energy intensive sector - and the rise of the service sector - a less energy intensive one - measured as a share of GDP.

[2] Mainly, the adoption of central heating and air-conditioning systems, the development of compact fluorescent lamps, and the adoption of urban shade-trees and light-colored surfaces.

Unipol Process, introduced in the mid 1970s, required a plant much smaller, produced twice as much product, and lowered the energy efficency of polyethylene production from 8400 BTUS per pound to 1500 BTUS per pound[3]. Based on the above discussion we conclude that the assumption of energy saving technological change being endogenous is a reasonable one and, more importantly, that the development of the technologies behind the observed decline in energy intensity coincides with the energy crisis of 1973-1974.

Other authors have suggested a causal link between the energy crisis and the introduction of energy saving technologies. For example, Schurr [41] finds that the energy intensity of the U.S. economy started its long-run decline by the end of World War I and stabilized (actually had a small positive growth rate) during 1950-1973. He finds that energy intensity declined at a faster speed between 1973-1983 than any other period in the 20th century. He concludes that the introduction of energy-saving technologies resulting from the oil crisis is the main culprit for this faster decline. Popp (2002) uses patent data to analyze the impact of energy prices on energy-saving innovation. He finds that the number of successful patent applications of energy-saving technologies jumped up during the mid 1970's. The main conclusion of the author, based on econometric analyses, is that energy prices have a strong, positive impact on the number of energy-saving technologies.

The sections that follow present a theoretical model with an explicit causal link between energy prices and the introduction of energy-saving technologies. We calibrate the model so that it matches the main features of energy consumption of the U.S. economy. We then test for the asset pricing implications of the energy crisis and the energy-saving innovation that followed.

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[3] The list of energy saving technologies is long. The interested reader can find many more examples in Tester, Wood and Ferrari (1990).

3 The Model Economy

In this section we present a general equilibrium asset pricing model with capital accumulation. Production is undertaken by corporations which are in turn owned by infinitely-lived households. Energy, an input in production, is imported from abroad and there is trade balance each period. There are two types of capital-embodying technologies which differ only in energy intensities. As such, capital is technology specific and investment decisions are irreversible.

Prior to 1974, agents assume that energy prices are going to stay at the pre-crisis level forever. The energy crisis takes place in the beginning of 1974 and takes the agents in the model by surprise. After 1974, the model is deterministic and the agents have perfect foresight on energy prices.

The Stand-in household

The population in period t is denoted by N_t and η is the constant growth factor of population, so $N_{t+1} = \eta N_t$. The stand-in household's preferences are described by the following utility function

$$\sum_{t=0}^{\infty} \beta^t u\left(c_t\right) N_t$$

where c is per-capita consumption, and $u(.)$ is given by

$$u\left(c\right) = \begin{cases} \frac{c^{1-\sigma}}{1-\sigma} \text{ for } \sigma \neq 1 \\ \log\left(c\right) \text{ for } \sigma = 1 \end{cases}$$

where $1/\sigma$ is the constant intertemporal elasticity of substitution. Each member of the household is endowed with a unit of time each period which it supplies inelastically to the labor market. The household participates in a market for shares of the corporations. Owning a fraction s_t of the perfectly divisible share entitles the shareholder to the same fraction of the dividends paid by the firm. The stand-in household's period zero budget constraint given by

$$\sum_{t=0}^{\infty} p_t \left[N_t c_t + V_t \left(s_{t+1} - s_t\right)\right] = \sum_{t=0}^{\infty} p_t \left[w_t N_t + d_t s_t\right]$$

where V is the price and d is the dividends per share of the firm.

The household's problem is to choose sequences of consumption $\{c_t\}$ and asset holdings $\{s_t\}$ that maximize utility subject to the period zero budget constraint.

Corporations

There is a unit measure of identical corporate firms, which operate two constant returns to scale technologies indexed by 1 and 2. Both these technologies use capital k, labor n and energy e as inputs to produce an identical output good $y = y_1 + y_2$ where

$$y_1 = \left[\min\{k_{1t}, \xi e_{1t}\}\right]^{\alpha} \left(A_t n_{1t}\right)^{1-\alpha} \quad \text{and} \quad y_2 = \left[\min\{k_{2t}, \phi_t e_{2t}\}\right]^{\alpha} \left(B_t n_{2t}\right)^{1-\alpha}$$

ξ and $\{\phi_t\}$ are parameters governing the energy-efficiency of each of the available technologies.[4] There is a minimum level of capital $\overline{k}_i$ requirement for each technology before that technology is operational and can be used to produce output [c.f. [4]]:

$$y_{it} = 0 \quad \text{if} \quad k_{it} < \overline{k}_i \quad \text{for} \quad i = 1, 2$$

A_t and B_t are the levels of labor-augmenting productivity at period t for type 1 and type 2 technologies correspondingly. Before each type of technology is adopted (i.e. when $k_i < \overline{k}_i$ for $i = 1, 2$), there's uncertainty regarding the initial level of productivity which prevails once the technology is operational. Let τ_i be the first period with $k_i > \overline{k}_i$. Then A_{τ_i} can take two values; A_0^g with probability π and A_0^b with probability $(1-\pi)$. Similarly B_{τ_i} can take two values; B_0^g with probability π and B_0^b with probability $(1-\pi)$ There is no further uncertainty; once a technology is adopted, it grows at an exogeneous

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[4] Note that the energy-efficiency of the second technology is time-dependent and will increase over time. We need this feature to match the observed decline in energy-output ratios.

factor γ (i.e. $A_{t+1} = \gamma A_t$ and $B_{t+1} = \gamma B_t$).

The law of motion for capital accumulation for each type of capital is given by

$$k_{it+1} = (1 - \delta) k_{it} + x_{it} \quad \text{for} \quad i = 1, 2 \tag{1}$$

where x_i is investment in capital type i and δ is the depreciation rate. Note that capital is technology specific, and investment decisions are irreversible in the sense that once investment is decided on a certain type of capital, that capital cannot be transformed into the other type of capital.

The corporations hire labor services and import energy from abroad, but they own their capital and in turn pay dividends d to their shareholders. Shareholders are the residual claimants on the income of corporations, hence dividends are equal to firm income less payments for wages, energy and new investments:

$$d_t = y_t - w_t (n_{1t} + n_{2t}) - p_t^e (e_{1t} + e_{2t}) - x_{1t} - x_{2t}$$

where p^e is the relative price of energy. The objective of the corporations is to choose sequences of investment $\{x_{it}\}$, labor $\{n_{it}\}$and energy $\{e_{it}\}$ for $i = 1, 2$ so as to maximize the present value of dividends:

$$\sum_{t=0}^{\infty} p_t d_t$$

Feasibility

The economy's resource constraint is now given by

$$N_t c_t + x_{1t} + x_{2t} + p_t^e (e_{1t} + e_{2t}) = y_t, \quad \text{for all } t. \tag{2}$$

Note that the above specification dictates a trade balance each period, where energy imports from abroad are paid off fully, and there is no foreign borrowing or lending. The market clearing in the labor market is given by

$$N_t = n_{1t} + n_{2t}$$

Finally, there is a market clearing condition for market for shares, which requires $s_t = 1$ for all t.

3.1 Tobin's (average) q

Tobin's average q is defined as the ratio of market value to the replacement cost of capital. In the model described above, market value corresponds to V_t. Furthermore, constraints (1) and (2) force the relative price of new capital to equal one, and thus the replacement cost of capital (at the end of period t) is $k_{1t+1} + k_{2t+1}$. Hence, Tobin's average q in this model is

$$q_t = \frac{V_t}{k_{1t+1} + k_{2t+1}}.$$

As is well known, a necessary condition for q to fall below one is that at least one of the irreversibility constraints binds. Intuitively, the amount of energy-inefficient capital (type 1) becomes "too big" with the increase in energy prices. In a world where investment decisions are reversible or capital is not technology specific, agents would transform this extra capital into consumption or would utilize it in the energy-efficient technology. Since they are not allowed to do either, the price of installed capital of type 1 falls. The magnitude of the fall is dependent on how much these constraints bind.

4 Calibration and Results

In this section we discuss how the model was calibrated and computed. Also we lay out the findings from the model and compare them with the data.

4.1 Calibration

To calibrate the parameters of the model, we follow Cooley & Prescott [8] and match certain features of the us economy in the pre-crisis period of 1962-1972 to the balanced growth path of the model. We set η equal to 1.01 to match the 1% average growth rate of population, and γ equal to 1.02 to match the average per capita growth rate of U.S. corporate output which is 2%. α is calibrated to match one minus the labor share of income in the corporate sector, obtaining a value for α of 0.33. σ governs the intertemporal elasticity of substitution and we take this number from Prescott [35], and let $\sigma = 2$. We set β equal to 0.998 to match a steady state real interest rate of 5% and δ equal to 0.06 to match an investment-output ratio of 20% and capital-output ratio of 1.5.

We have assumed that the oil crisis was completely unexpected and prior to the crisis, agents expected energy prices to remain constant in theri 1972 levels. Prior to the crisis, corporations were endowed with only type one capital, and they had not made any investment in type two capital. We choose the minimum investment requirements and also the initial productivity parameters and probabilities such that given the expectations on energy prices[5], agents would choose not to adopt the second technology and only operate the first technology prior to the crisis, but they adopt the second, more energy-efficient technology once the oil shock occurs. With these considerations, we set $\overline{k}_1$ equal to zero, and $\overline{k}_2$ to 0.20 which is 10% of the total capital stock. Since the first technology has already been adopted, the initial level of productivity for technology 1 is irrelevant. We set the initial level of productivity of technology 2 in the good state equal to technology 1's level of productivity (i.e. $B^g_{\tau_2} = A_{\tau_2}$) and in the bad state 10% lower. π is set equal to 0.45.

Finally, we set ξ so that the model's energy use to output ratio matches the 1962-72 U.S. average, and compute the sequence $\{\phi_t\}_{t=1973}^{2001}$ that minimizes the distance between the equilibrium energy output ratio from the model, and the associated data series. The resulting sequence is plotted in Figure 5:

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[5] Note again that prior to 1974, agents believe the energy prices are going to stay at their pre-crises level forever. Once the energy crises occurs, they have perfect foresight on energy prices.

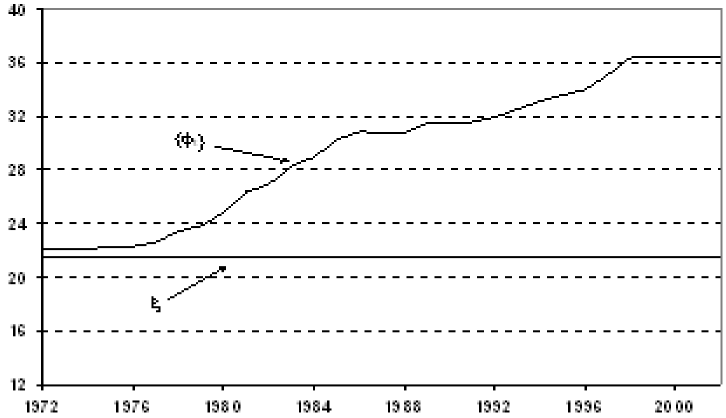

Figure 5: The parameters regulating energy-intensity of the two technologies

4.2 Findings

As previously described, the energy-saving properties of the new technology are such that the model matches the observed energy output ratio: in spite of the sharp decrease in energy prices in the 80's, energy use declines monotonically, as in the data. The energy output ratio from the model and of the U.S. corporate sector are shown in Figure 6 below:

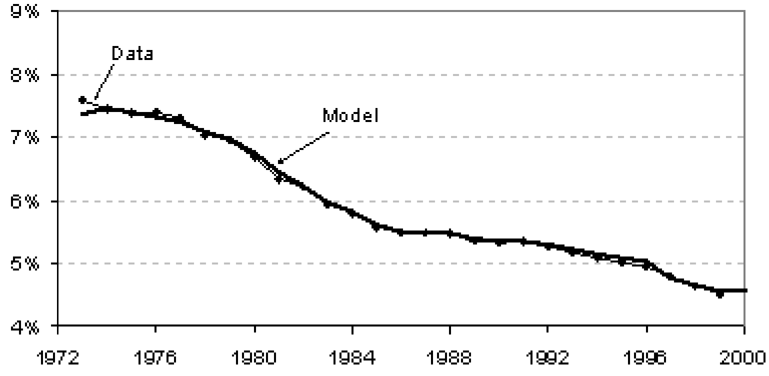

Figure 6: Energy-output ratio: model vs. data

The observed changes in energy prices, coupled with the availability of a new technology with energy saving factor $\{\phi\}$, translate into a 25% drop in market valuations, about 1/2 of what is observed in the data. The model's predictions for q, and its U.S. data counter part are plotted in Figure 7 below:

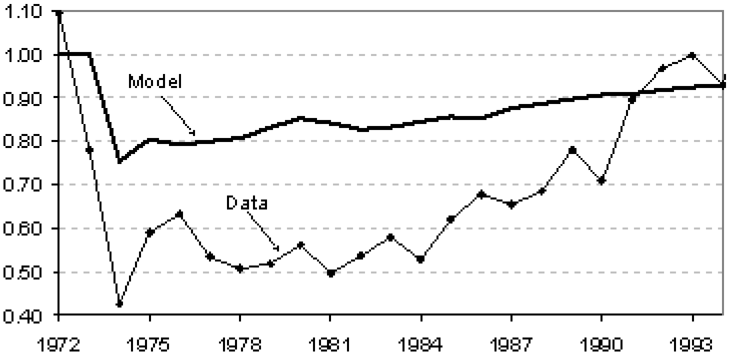

Figure 7: Tobin's q: model vs. data

The increase in energy prices generates a modest slowdown in output as shown in the following graph:

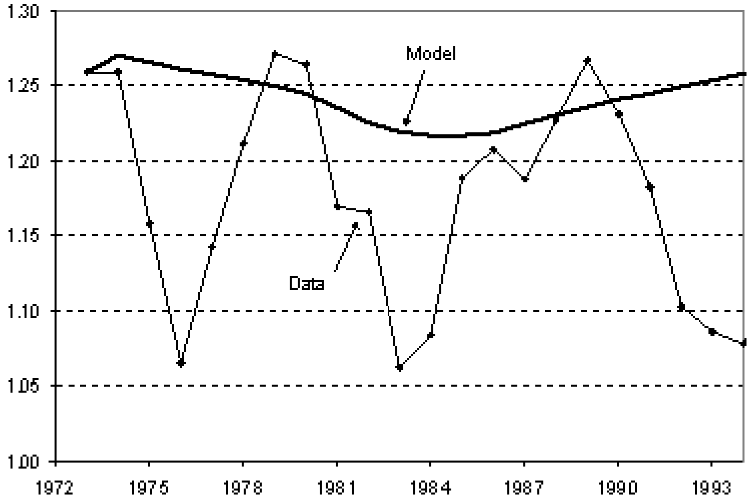

Figure 8: Output: model vs. data

It also generates a strong contraction in investment. We believe the latter is due to the simplicity of our model. We have abstracted from changes in investment tax credits, from the impact of the productivity slowdown, and from the increasing importance of information technologies. All of those changes are known to make investment increase and, more importantly, to generate sudden drops in market valuations (cf. McGrattan and Prescott [29], Boldrin and Peralta-Alva [5], and Peralta-Alva [33]).

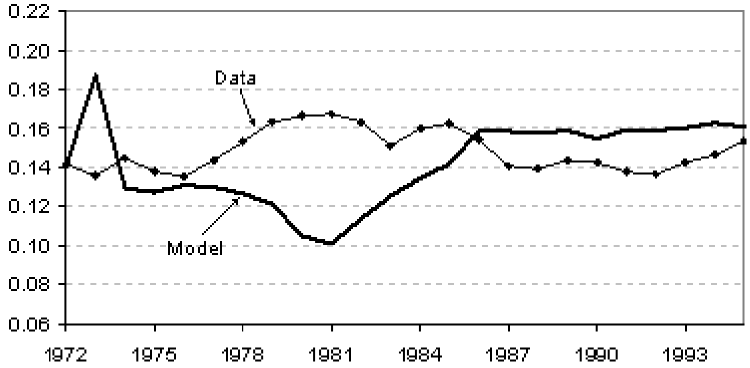

Figure 9: Investment-output ratio: model vs. data

5 Conclusion

This paper employs a calibrated dynamic general equilibrium model to evaluate how much of the stock market crash of 1973-74 can be accounted for by changes in energy prices. In a world where capital is technology specific, and investment decisions irreversible, we find that the observed changes in energy prices, together with the energy-saving technologies derived from the energy use series data, translate into a 25% drop in Tobin's average q. This corresponds almost half of the observed drop in q of the mid-70's . Our model is qualitatively consistent not only with the data patterns in equity prices, but also with the economic slowdown of the mid-70's.

The basic economic mechanism we considered is the following: A sudden increase in energy prices renders old capital obsolete, and causes its market valuation to collapse. Old technologies are abandoned and gradually replaced by energy saving ones, better suited for the new economic conditions. Old capital is left to depreciate, and labor flows from the old to the new type of technology. The replacement process is gradual, and market values recover in a smooth fashion.

In our model, the possibility of adoption of a new energy-saving technology is always available, but costly, hence agents do not introduce it unless the economic conditions demand it. We believe that the energy price increase of 1973-74 gave agents enough incentives to pay the cost, and to innovate in such energy saving technologies.

Our analysis indicates that changes in energy prices should be part of any theory of the stock market collapse of 1973-74.

6 Data Appendix

Here we outline how the major series used in the figures were constructed.

Figure 1. Ratio of Market Value to Replacement Cost of Tangible Assets for Corporations

Market value of corporations was constructed using data from the *Flow of Funds Accounts of the United States* (FOF) issued by the Board of Governors of the Federal Reserve System (FRB).[6] In the FOF, domestic corporations are divided into nonfinancial and financial corporate business. Financial corporations are further divided to the following categories as listed in Table F.213: Commercial banking, life insurance companies, other insurance companies, closed-end funds, exchange-traded funds, real estate investment trusts (REITs) and brokers and dealers.

Our measure of market value reflects both equity value and debt of all domestic corporations, and all direct or indirect (through mutual funds) intercorporate holdings of corporate equity and debt has been netted out. To that effect market value of domestic corporations (MV) has been constructed as follows:

MV = Corporate equity issued by nonfinancial and financial corporate businesses + Net financial liabilities (i.e. Total liabilities - total financial assets) of nonfarm nonfinancial corporate businesses,commercial banks, life in-

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[6] This data can be downloaded from the FRB website at http://www.federalreserve.gov/releases/z1/current/data.htm.

surance companies, other insurance companies, closed-end funds, exchange-traded funds, REITs, and security brokers and dealers.

Replacement cost of tangible assets of corporations was constructed using data from the *Fixed Assets Tables* (FA) reported by the Bureau of Economic Analysis (BEA)[7] and also from the FOF. Our measure of tangible assets include all nonresidential and residential fixed assets, plus inventories. Corporate fixed assets are the sum of corporate nonresidential fixed assets and corporate residential fixed assets. Stock of inventories held by nonfarm nonfinancial corporations is from the FOF. We assume financial corporations hold no inventories as their inventory investment is zero in the product account, and we neglect inventories hold by farm corporations since they are negligibly small.

Figure 2. Energy Prices relative to the GDP Deflator

We follow the methodology outlined in Atkeson & Kehoe [2] and construct an energy price deflator from a weighted average of coal, natural gas, petroleum and electricity consumed in the commercial, industrial and the transportations sectors. This excludes residential consumption as we focus only on the business sector and also energy consumed by the electric power sector as in our model all energy is imported. We use quantity and price data reported in the Annual Energy Review (AER) 2001.[8] The quantity of each type of energy (measured in units of Btu) consumed in the commercial, industrial and the transportation sectors are from Tables 2.1c, 2.1d, 2.1e respectively. For prices we use consumer price estimates of energy (as businesses are consumers of energy) reported in Table 3.3 and we label the price of energy for each type as P_i. For each type of energy i, we add the consumption of that energy type in all sectors and call that Q_i. Then, total energy expenditure is simply $\sum_i Q_{it} P_{it}$. We calculate real energy use using 1972 prices as the base year. Hence real energy use equals to $\sum_i Q_{it} P_{i1972}$. The energy price deflator P_t is simply the ratio of the total energy expendi-

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[7] This data can be downloaded from the BEA website at http://www.bea.doc.gov/bea/dn/faweb/AllFATables.asp.

[8] This data can be downloaded from the EIA website at http://www.eia.doe.gov/emeu/aer/contents.html.

ture to total energy use:

$$P_t = \frac{\sum_i Q_{it} P_{it}}{\sum_i Q_{it} P_{i1972}}$$

The GDP deflator is constructed in the usual way from nominal and real GDP series reported in BEA's NIPA Tables 1.1 and 1.2.

Figure 3. Energy Expenditure and use in the Business Sector

Total energy expenditures of the business sector was calculated as in Figure 2 and then was divided by the nominal GDP of the business sector (from NIPA). The total real energy use of the business sector (expenditure using 1972 prices) was calculated as explained for Figure 2. This number was divided by the real GDP of the business sector in 1972 prices. Real GDP of the business sector data is from BEA's NIPA Table 1.8. These numbers are reported in 1996 dollars. We first construct a price deflator using nominal and real GDP of the business sector, readjust the level of the deflator such that 1972 = 1 rather than 1996. Then we multiply this number with nominal GDP of business to get real GDP of business in 1972 dollars.

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