Can technological change explain the stock market collapse of 1974?

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ABSTRACT

This paper uses dynamic general equilibrium models to quantitatively test the idea that technical change caused the stock market collapse of the mid 1970's, its subsequent stagnation, and recovery. First, I consider the hypothesis that the arrival of information technologies (IT) rendered old capital obsolete, and led to a collapse of equity prices. I find that shocks necessary for the IT-revolution to cause the observed drop in Tobin's q imply a two-fold increase in aggregate investment, and a strong expansion in GDP and consumption. Such predictions are orthogonal to what one observes in the data. Next, I consider the hypothesis that the productivity slowdown of the mid 1970's caused an unexpected decrease in the growth rate of shareholders' income, causing equity prices to fall. This hypothesis is consistent with the behavior of aggregate quantities and it delivers a large decrease in market values, but is not capable of producing the persistently low values of q that characterize the data. My analysis indicates that the main challenge for a general equilibrium explanation of stock market behavior resides in reconciling the movements of Tobin's q with those of aggregate investment.

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1. Introduction

The U.S. economy witnessed two important technology shocks during the mid 1970's. First, the growth rate of total factor productivity decreased by a factor of three around 1974 and stagnated for the following two decades [cf. Norsworthy et. al. (1979), Baily (1981), Jorgenson (2000)]. Second, it has been argued that the mid 1970's marked the beginning of a new industrial revolution, associated with the introduction of information technologies [cf. Greenwood and Yorukoglu (1997), Greenwood and Jovanovic (1999), Hobijn and Jovanovic (2001)]. These changes in technology coincide with some of the most dramatic, long lasting, fluctuations that the U.S. stock market has experienced. During 1973-74 the market value of existing corporations[1], shown in Figure 1 as ratio of their net capital stock[2] (i.e., Tobin's average q), decreased by 50% and did not recover until the mid 1990's.

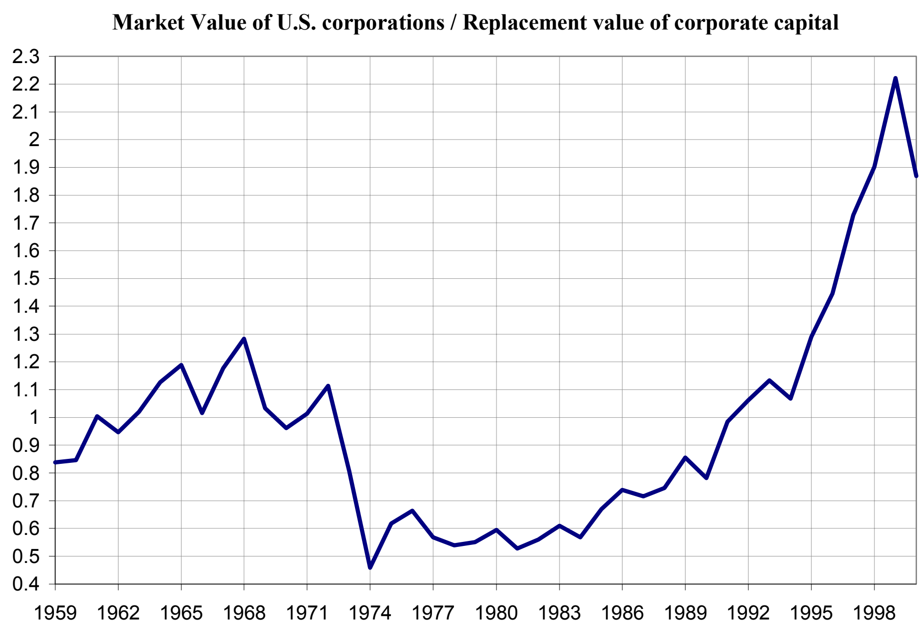


Figure 1

A growing literature suggests that there is, in fact, a causal link between these two events, and that technological change has been the main force driving fluctuations in equity prices.

[1]Flow of Funds, Table L213, Line 1: issues at market value plus the value of net corporate debt; net corporate debt equals Total financial liabilities of the corporate sector (Flow of Funds series FL104190005.Q) minus its total financial assets (Flow of Funds series FL104090005.Q)

[2]Net stock of non-residential fixed assets of the corporate sector, from table 4.1 of the BEA's fixed assets tables, plus the flow of funds measure of the value of corporate inventories

Broadly speaking, two main hypotheses have been formulated: The first one is the "good news" hypothesis according to which it was the arrival of information technologies that rendered old capital obsolete, and caused a collapse in its market value [e.g. Greenwood and Jovanovic (1999), Hobijn and Jovanovic (2001) and Laitner and Stolyarov (2001)]; The second one is the "bad news" hypothesis, according to which the slowdown of the mid 1970's caused an unexpected drop in the growth rate of shareholder's income, and that is why equity prices fell [e.g. Boldrin and Levine (2001), Hall (2001)].

The purpose of this paper is to measure the extent to which technological change can provide us with a consistent explanation of the stock market collapse of 1974, as well as its subsequent stagnation and recovery. A particular emphasis will be given to the study of what Hall (2001) calls the "single hardest episode to understand" about the behavior of U.S. equity markets: the market value of U.S. corporations was much lower than the replacement cost of their assets, i.e. Tobin's average q was lower than one, all over the 1974-1989 period.

The framework of analysis of this study is the one given by an intertemporal general equilibrium theory of capital asset pricing. The rules of the exercise are simple: a model will be considered successful if it can account for the observed movements in equity prices, and if it is also consistent with the observed secular patterns of GDP, consumption and investment.

To evaluate the quantitative aspects of the "good news" hypothesis, I use a one-sector neoclassical growth model where investment decisions are irreversible, and capital is technology specific. Such assumptions allow for q to be smaller than one. Following the literature, I consider two different types of technology shocks: In the first one agents learn of the future arrival of a new, better, technology [as in Greenwood and Jovanovic (1999) or Hobijn and Jovanovic (2001)] and realize that existing production methods, and all of the capital therein installed, are about to become obsolete. A calibrated version of the model shows that information alone has no effect on Tobin's average q. Then I consider a second type of shock which consists of the actual arrival of a new, better, technology [as in Laitner and Stolyarov (2001)]. My numerical experiments show that, in the extreme setup where capital is completely irreversible, and immobile across existing technologies, for equity prices to fall as much as in the data, the model must imply a two-fold increase in investment, and a strong and sustained expansion in GDP and consumption. All of these predictions are inconsistent with the U.S. experience.

For symmetry with the previous analysis, I start by evaluating the "bad news" hypothesis within the framework of a one sector neoclassical growth model. I study the effects of a sudden, and unexpected, slowdown in the growth rate of total factor productivity and find that this theory can deliver patterns for GDP, consumption and investment compatible with the ones in the data, but that it cannot account for the observed fluctuations in Tobin's q. In the one sector neoclassical growth model, total output can be freely allocated among capital and consumption and the relative price of capital is always equal to one, which makes the model unsuitable for the study of equity price movements. To give a fair treatment to the "bad news" hypothesis, one has to move away from a one-sector, one-capital framework. I do so by considering a simple version of the economy described by Boldrin and Levine (2001), which includes many types of capital, and an explicit distinction between capital and consumption goods. There, an unexpected economic slowdown generates a substantial drop in the market value of existing capital. Further analysis shows that this model cannot account for the most prominent feature of the data: the persistently low values of q.

The paper concludes by pointing out that the main challenge for a general equilibrium explanation of stock market behavior resides in reconciling the observed movements of Tobin's average q with those of aggregate investment.

2. The secular trends of the U.S. economy

As previously discussed, a theory will be considered successful if it can account for the movements in Tobin's average q as illustrated in Figure 1, and if it is also consistent with the secular patterns of GDP, consumption and investment present in the data. The purpose of this section is to provide a reasonable measure for the latter patterns.

The model economies that this paper studies are very abstract: they contain no government sector, no household production sector, no foreign sector, and no explicit treatment of inventories. Consequently, the first thing one has to consider is how to use the U.S. National Income and Product Accounts (NIPA) to construct measures consistent with the concepts of the theory. A summary of such a procedure, based on Cooley and Prescott (1995), follows.

The NIPA are somewhat inconsistent in that the output of some important parts of the capital stock are not included in measured output (GDP). The accounts include the flows of services from owner-occupied housing as part of GDP, but they do not attempt to impute the flow of services from the stock of consumer, or government, durable goods. In the model economies considered here, output includes the output produced by all existing types of capital and thus, to obtain a consistent measure, one has to add to the NIPA GDP the flows of services of consumer and government durables.

Regarding investment expenditures, the U.S. NIPA reports separate measures for the private and the government sector; changes in inventories, which are another type of investment, are also independently reported. On the other hand, the NIPA treat new purchases of durable goods as a type of consumption while, conceptually, they constitute a form of investment. All of these investment expenditures have to be aggregated into a single measure so as to be consistent with the simple model economies analyzed by this paper. Thus,

Aggregate investment = NIPA Private domestic investment+Net exports+Government Investment+Inventories+New purchases of consumer and government durable goods.

In the theories here analyzed the following accounting identity will always hold

$$\text{GDP} = Investment + Consumption.$$

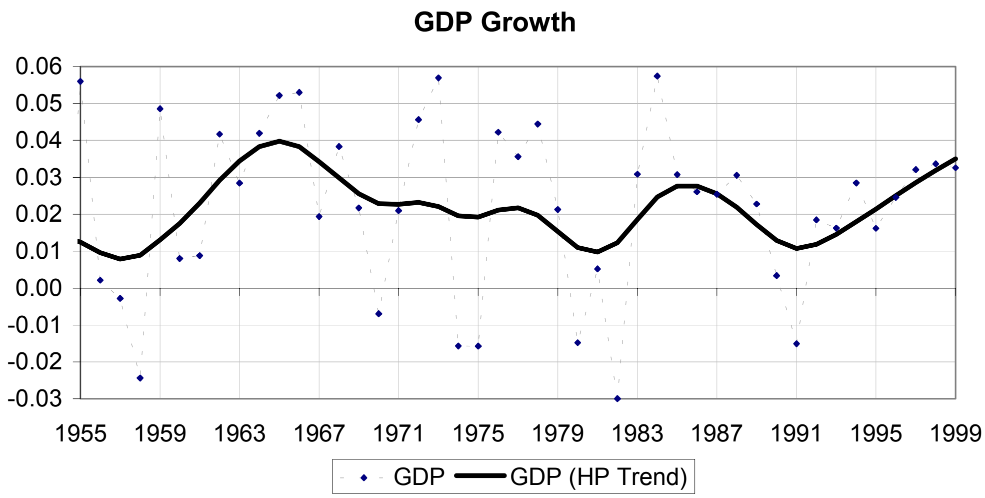
When dealing with the data, and based on the previous measures of GDP and investment, for the above equality to hold, measured consumption must be defined as follows:

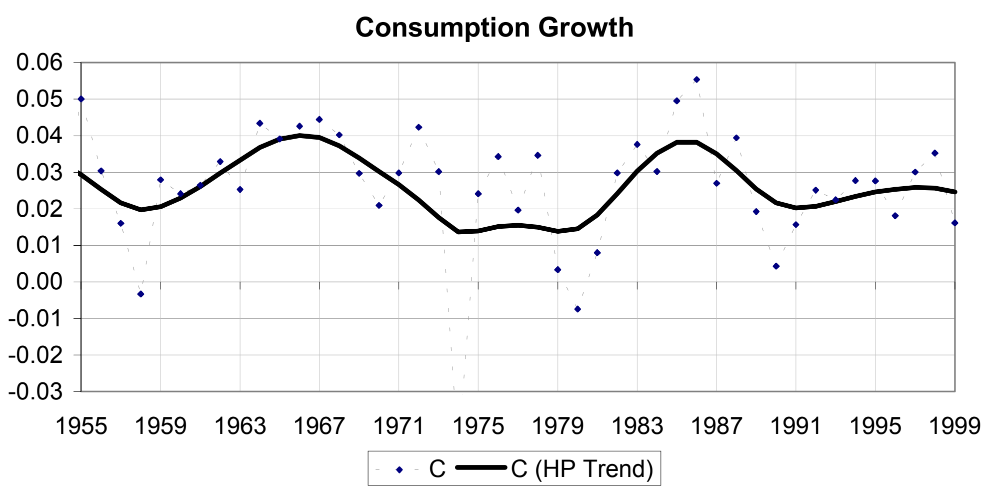
Consumption= NIPA's personal consumption expenditures (other than new purchases of durable goods)+NIPA's Government expenditure (other than investment or durable good purchases)+Flow of services from the stock of durable goods.

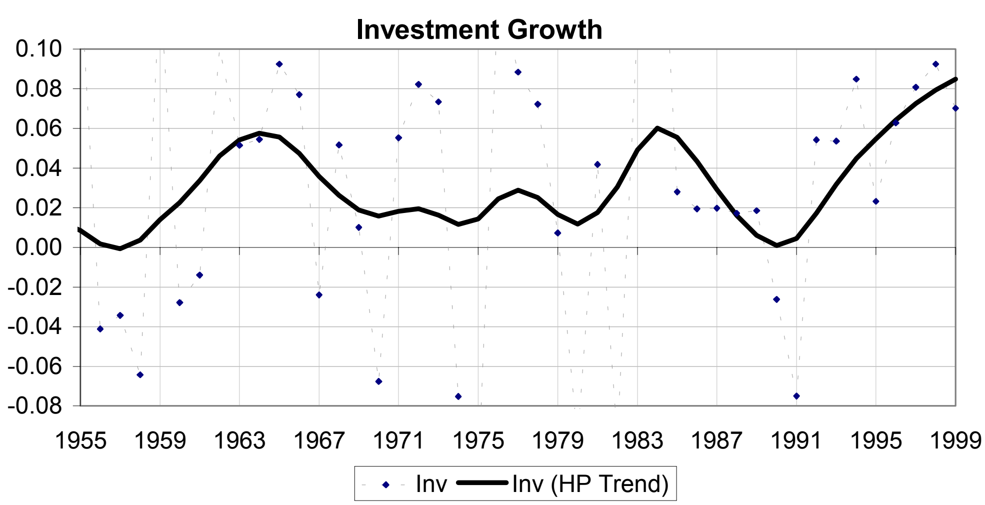
This paper concentrates on the study of the secular patterns of the stock market and therefore, it abstracts from business cycle details. The predictions for each of the models here evaluated should only be compared with the low frequency movements of the data. To measure those I use the Hodrick-Prescott trend of each of the associated time series.[3] The following figures

[3] I am using annual data, and I have used a smoothing parameter λ=10, which is within the range of values suggested by the literature [cf. Ravn and Uhlig (2002)]

show the results. All variables are in per capita terms and are measured in chained dollars with base year 1996.







The most important features of the data are:

1. All variables display a remarkable slowdown that starts around 1965;
2. the growth rate of all variables decreases monotonically over the 1965-79 period;
3. from 1979 to 1986 the economy gradually recovers. A further slowdown starts around 1987 and culminates with the large 1991 recession;
4. finally, the mid 1990's constitute a period of expansion. In particular, GDP experiences a quick recovery fueled by the strongest expansion in investment of the whole sample period.

This helps us in sharpening the definition of a successful model as one that accounts for the patterns of Tobin's q described by Figure 1, and that is also consistent with facts 1-4 above.

3. Good news models: The IT revolution

This section describes a general equilibrium asset pricing model with capital accumulation and production, based on Brock (1980), which will be used to evaluate the quantitative implications of the "good news" hypothesis. The model is a generalization of those developed by Greenwood and Jovanovic (1999), or Hobijn and Jovanovic (2001), in that agents can accumulate productive assets. Capital is assumed to be technology specific and irreversible, as is standard in the literature [e.g. Dixit and Pindyck (1994), Sargent (1980)]. Such assumptions allow for the market value of installed capital to be lower than its replacement cost (so that q can be lower than one, as in the data)[4].

After describing the basic framework of analysis I give a definition of a competitive equilibrium and, finally, the model's measure of Tobin's average q.

A. Households and equity markets

Preferences of the representative household are described by

[4] This environment is an extreme case of a world where capital can be moved, and uninstalled, at a cost. As long as the marginal cost of uninstalling capital, or moving it, is positive, it is also true that the market value of the firm can be lower than its replacement cost. Jovanovic and Rousseau (2002) consider such a framework, and find that the Information technology revolution can only account for a 7% decrease in Tobin's average q.

$$\sum_{t=0}^{\infty} \beta^t u(c_t),$$

where t indexes time and c is per-capita consumption. Each household has n_t units of time, and supplies them inelastically to the labor market. The problem of the household consists of choosing the sequences of consumption and asset holdings that maximize utility subject to its budget constraint

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

$$s_t \geq 0, \;\; s_0 \text{ given.}$$

Expenditures are consumption, c_t, and net purchases of shares in stocks, $V_t(s_{t+1} - s_t)$; s_t denotes the number of shares held at the beginning of period t, and V_t is the price per share. Household's income equals labor earnings, $w_t n_t$, plus total dividend income, $d_t s_t$; d_t denotes dividends per-share, and w_t is the wage rate.

At every given period there is one perfectly divisible equity share outstanding. Hence, market clearing in the market for shares requires $s_t = 1$ for all t.

B. Firms and aggregate resource constraints

Firms have two different types of capital, k_{1t} and k_{2t}, and hire labor to produce output with a constant returns to scale technology. The level of technology, A_t, follows a deterministic exogenous process. The problem of the firm consists of finding the sequences of investment and labor that maximize the present value of dividends

$$\max_{x_{1t}, x_{2t}, n_t} \sum p_t \left[F(k_{1t}, k_{2t}, A_t n_t) - w_t n_t - x_{1t} - x_{2t}\right]$$

$$s.t.$$

$$k_{1t+1} = x_{1t} + (1-\delta)k_{1t}$$

$$k_{2t+1} = x_{2t} + (1-\delta)k_{2t}$$

$$A_{t+1} = \gamma A_t$$

$$x_{1t}, x_{2t} \geq 0 \qquad (1)$$

given $A_0, k_{1,0}$ and $k_{2,0}$.

The constraints in (1) imply that investment is irreversible: newly produced goods can be either consumed or used to augment the capital stock. But once designated as a given type of capital they cannot be physically converted into consumption.
Finally, the economy's aggregate resource constraint is

$$x_{1t} + x_{2t} + c_t = F(k_{1t}, k_{2t}, A_t n_t) = y_t \text{ for all } t$$

C. Competitive equilibrium

A competitive equilibrium is a sequence of prices $\{p_t, V_t\}$ and allocations of consumption, asset holdings, investment, capital, and labor $\{c_t, s_t, x_{1t}, x_{2t}, k_{1t}, k_{2t}, n_t\}$ such that

1. Given prices, $\{c_t, s_t\}$ are a solution to the household's problem
2. Given prices, $\{x_{1t}, x_{2t}, k_{1t}, k_{2t}, n_t\}$ solve the problem of the firm, and
3. Markets clear, so that $\{c_t, s_t, x_{1t}, x_{2t}, k_{1t}, k_{2t}, n_t\}$ satisfy the aggregate resource constraint, and $s_t = 1$ for all t.

Remark 1. In terms of period t consumption, the cost of producing a new unit of capital equals one. Hence, the replacement cost of the firm's capital stock, per-unit, is equal to one.

To relate the current model to the measure of Tobin's average q in Figure 1, note that total market capitalization, the numerator of q, equals V_t; on the other hand, the replacement cost of the stock of capital of the firm, in units of period t consumption, equals $k_{1t} + k_{2t}$. The latter is the denominator of q, and thus

Definition 1. *Tobin's average q equals*

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

The previous model abstracts from organizational capital, which gives this theory its best chance at explaining the low market valuations of the mid 1970's. As Hall (2000, 2001a) points out, if one includes intangibles into the analysis then one also has to rationalize why their value suddenly disappeared during the mid 1970's, or, even harder, why firms chose to accumulate assets of negative value for more than a decade. Including adjustment costs causes the price of installed capital to be larger than one, and that is why I also excluded them from the present analysis.

I will now use the previous simple model to obtain the quantitative implications of the good news hypothesis.

4. Good news models: The effects of "good news" on equity prices

A. The economic environment before the shock

Following Hobijn and Jovanovic, assume capital of type two is not available, so that both, k_{20} and x_{2t} are constrained to be zero, that F is homogeneous of degree one, and that the share of total income going to labor is constant and equal to $1-\alpha$. Any changes in this state of affairs is thought to be impossible. To simplify the analysis, and guarantee monotone convergence to a balanced growth equilibrium, I will also assume that both, the production and utility function satisfy the following Inada-type conditions: F and u are strictly increasing, strictly concave, and $\lim_{k_{1,t}\to 0} F(k_{1,t}, 0, An) = \infty$, $\lim_{k_{1,t}\to\infty} F(k_{1,t}, 0, An) = 0$, $\lim_{c\to 0} u(c) = \infty$ and $\lim_{c\to\infty} u(c) = 0$.

The following result characterizes the equilibrium behavior of Tobin's average q under the aforementioned assumptions

Proposition 1. *Whenever the irreversibility constraint binds* $q < (1-\delta)$; *otherwise* $(1-\delta) \leq q \leq \frac{k_{1,t+1}}{k_{1,t}}$

Proof. The consumer's first order conditions with respect to s_{t+1} and c_t imply

$$(2) \quad p_t V_t = p_{t+1}\left(d_{t+1} + V_{t+1}\right).$$

On the other hand, the firm's first order condition with respect to $k_{1,t+1}$ delivers

(3) $\quad p_t - \mu_t = p_{t+1}\left[(1-\delta) + F_1(k_{1,t+1}, 0, A_t n_t)\right] - \mu_{t+1}(1-\delta),$

where μ_t is the multiplier of the irreversibility constraint (1). The share of total output going to labor is $1-\alpha$, and dividends equal

$$d_{t+1} = \alpha F(k_{1,t+2}, 0, A_{t+2}n_{t+2}) - x_{1,t+1}.$$

One can multiply both sides of (3) by $k_{1,t+1}$ and use the homogeneity of F, the law of motion of capital, and the above expression for dividends to get

(4) $\quad (p_t - \mu_t)k_{1,t+1} = \left(p_{t+1} - \mu_{t+1}\right) k_{1,t+2} + p_{t+1}d_{t+1}.$

Without loss of generality set $p_0 = 1$, equations (2) and (4) imply

$$V_0 = \lim_{T\to\infty} \left\{ \sum_{t=1}^{T} p_t d_t + p_T V_T \right\} \quad (5)$$

$$(1-\mu_0)k_1 = \lim_{T\to\infty} \left\{ \sum_{t=1}^{T} p_t d_t + (p_T - \mu_T)\, k_{1,T+1} \right\} \quad (6)$$

$$p_t V_t - p_{t+1}V_{t+1} = (p_t - \mu_t)\, k_{1,t+1} - \left(p_{t+1} - \mu_{t+1}\right) k_{1,t+2}. \quad (7)$$

It is well known that, in equilibrium, all variables converge to a balanced growth path, which is independent of the given initial conditions [cf. Arrow and Kurz (1970), or Olson (1989)]. In a balanced growth path investment is strictly positive and thus, by continuity, there is a τ, large enough, such that for all $t \geq \tau$ investment is strictly positive, and $\mu_t = 0$. Hence, equations (5), (6), the transversality condition for the problem of the firm $[\lim_{T\to\infty} p_T k_{1,T+1} = 0]$, the one for the consumer $[\lim_{T\to\infty} p_T V_T s_{T+1} = 0]$, and the market clearing condition ($s_t = 1$ for all t) imply $V_0 = (1-\mu_0)k_1$. Using this as initial condition for the difference equation in (7) delivers the following equilibrium relation between the market value of a firm and its capital stock

$$(8) \quad V_t = (1 - \frac{\mu_t}{p_t}) k_{1,t+1} \text{ for all } t.$$

To prove the first statement of the proposition note that μ_t is strictly positive only when the irreversibility constraint binds; in that case, equation (8) says $V_t < k_{t+1} = (1-\delta)k_t$ and the definition of q delivers $q_t < 1-\delta$. To prove the second one assume the irreversibility constraint does not bind, then $\mu_t = 0$, $V_t = k_{t+1}$ and $q_t = \frac{k_{t+1}}{k_t} \geq (1-\delta)$. **Q.E.D.**

Proposition one outlines why the market value of installed capital can be lower than its replacement cost: in a world where investment decisions are *reversible* if, for any reason, agents have "too much" capital, it is possible to consume some of it, and capital returns to its optimal level. In a world where capital is *irreversible* agents are prevented from recurring to such mechanism. If there is too much capital installed in a given technology, the associated irreversibility constraint will bind, and its price will fall below one.

B. News arrives at date zero

In an optimal growth economy, like the one considered here, agents will never over-accumulate capital. Thus, unless the initial capital-output ratio is larger than the balanced growth one, the irreversibility constraint will never bind, and Tobin's q will never be lower than one minus delta. If the production possibility frontier changes in an unexpected manner, agents may find themselves with too much capital installed in a given technology, the irreversibility constraint may bind, and q may fall abruptly. This is the role that technology shocks play as a source of equity price movements.

I now consider the first type of "good news" shock. Assume that, in period $t = 0$ agents learn that capital of type two will become available at the beginning of date T, and that its arrival will raise output permanently, i.e. that for all $t \geq T$

$$F(k_{1t}, k_{2t}, A_t n_t) > F(k_{1t}, 0, A_t n_t),$$

for any $k_{2t} > 0$. Investment in capital of type two is constrained to be zero until the new technology arrives (i.e. after period T). No further shocks are expected.

Hobijn and Jovanovic argue that the main reason why the price of existing capital may fall as a result of the "good news" shock is that the new type of capital can displace old capital as an input, and that the largest impact would occur if the arrival of new capital made old capital fully obsolete. Following this ideas, I let

$$F \stackrel{def}{=} f(k_{1t}, A_{1t}n_{1t}) + f(k_{2t}, A_{2t}n_{2t})$$

because it allows for the complete abandonment of old capital, and provides an upper bound to the drop in market value the model can possibly generate. I now turn into analyzing what happens to asset prices and aggregate quantities at date zero, the time of the shock.

C. Testing the theory

A slight modification to the proof of proposition one, given in appendix one, can be used to show that, for all periods prior to the actual arrival of the new technology, the market value of existing capital can only fall below its replacement cost when the irreversibility constraint binds. Namely, that

$$q_t = \left(1 - \frac{\mu_t}{p_t}\right)\frac{k_{1,t+1}}{k_{1,t}} \geq \left(1 - \frac{\mu_t}{p_t}\right)(1-\delta) \text{ for all } t < T.$$

To build the best case for this theory[5] assume news about the future arrival of a new, better, technology really caused the observed stock market collapse and stagnation of the mid 1970's. According to the above expression for Tobin's average q, for this to happen the irreversibility constraint for capital of type one must bind, from the time of the shock, $t = 0$, up to period T. Regardless of the specific functional forms that f and u may take, the model has the following implication for the behavior of capital:

[5] In appendix two I study the effects of "good news" under standard functional forms for F and u; the associated numerical simulations show that such shock does not have any effects on Tobin's average q. Consumption for periods 0 through T can only come from the old technology, hence, in an optimum, investment decreases, but not all the way to zero. Then, the irreversibility constraint does not bind and Tobin's q is unaffected by the shock.

$$k_{1,t+1} = (1-\delta)^t k_{1,0} \text{ for } t = 0, ..., T.$$

If good news alone caused the observed twelve-year long stagnation of q, one should see capital falling at a 5% annual rate, which is the standard value for δ, over the 1972-84 period. This prediction is not consistent with the U.S. experience, where capital went up by 27% - in real, per-capita units - over the same time period.

In a world without capital accumulation, Hobijn and Jovanovic show good news can account for the movements in the market value of U.S. corporations to GDP ratio represented by the bold line in Figure 2

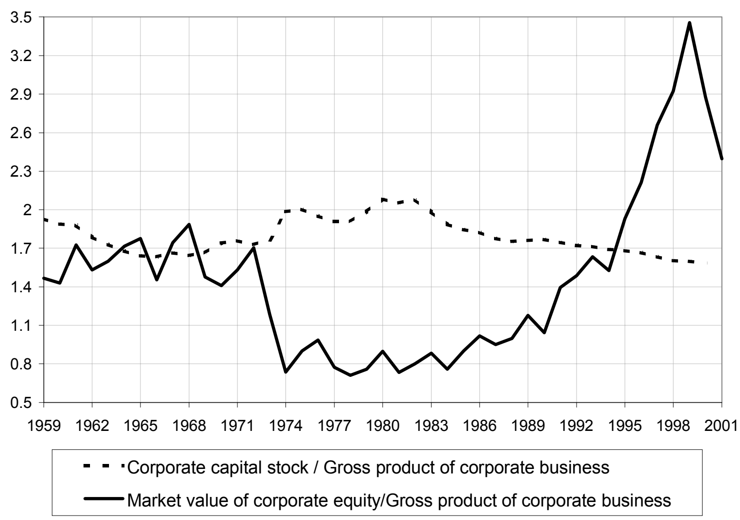


Figure 2

. Is this also possible in a model with capital like the one analyzed here? The answer is no. The previous argument rules out the possibility of a continuously binding irreversibility constraint. On the other hand, if the irreversibility constraint does not bind, the market value of the firm equals the value of its capital stock. If good news caused the observed drop in the market value to GDP ratio one should observe a 50% drop in the ratio of corporate capital to GDP around 1974 followed by a decade long stagnation. As can be verified by Figure 2 above, the corporate capital to GDP ratio actually went up (by 14%), and remained high, during the 1974-84 period.

The analysis of this section shows that, in a model that allows for capital accumulation, learning about the future arrival of a better technology could not have caused the 1974 stock market collapse, nor the stagnation that followed.

5. Good news models: The arrival of a new, better, technology

Laitner and Stolyarov (2001), and Jovanovic and Rousseau (2002), argue that the drop in equity prices of 1974 was caused by the actual arrival of a new, better, technology. The model of section three is now adapted to study the quantitative implications of this hypothesis.

A. The model

To do so it is necessary to assume specific functional forms for the production and utility functions. I pick a standard Cobb-Douglas formulation for f

$$F(k_{1t}, k_{2t}, n_1 + n_2) = k_{1t}^{\lambda_0}(A_{1t}n_{1t})^{1-\lambda_0} + k_{2t}^{\lambda_0}(A_{2t}n_{2t})^{1-\lambda_0},$$

and $u(c_t) = \ln(c_t)$.

Before the shock, the technology using capital of type two is not available, and investment in such type of capital is constrained to be zero. The growth rate of total factor productivity of technology one is given by $\frac{A_{1t+1}}{A_{1t}} = \gamma$. For simplicity, the economy is assumed to start at its balanced growth equilibrium. Agents expect these conditions to prevail forever.

B. The technology shock

In period T a new, better, technology arrives. It is better because its TFP level, and growth, are higher than that of the old technology[6]. In particular,

$$\begin{aligned} \frac{A_{2t+1}}{A_{2t}} &= \gamma' \geq \gamma \text{ for } T \leq t \leq T + M \\ \frac{A_{2t+1}}{A_{2t}} &= \frac{A_{1t+1}}{A_{1t}} = \gamma \text{ for } t > T + M \end{aligned}$$

[6] For q to fall at the time of the shock it is necessary that the new technology is more productive than the old one. To keep the analysis simple, it is assumed that, in the long run, both technologies can deliver the same consumption growth rate.

where $0 \leq M < \infty$

When taking the model to the data T will be assumed to be the year of 1973.

The following result characterizes the dynamic behavior of Tobin's average q in a very simple way.

PROPOSITION 2. *For q to be lower than $1-\delta$ it is necessary that at least one of the irreversibility constraints bind.*

Proof. Applying the method of proof of proposition 1 to this economy one can get

$$V_t = k_{1,t+1}\left(1-\frac{\mu_{1t}}{p_t}\right) + k_{2,t+1}\left(1-\frac{\mu_{2t}}{p_t}\right),$$

where μ_{1t} and μ_{2t} are the multipliers of the irreversibility constraints for each type of capital. Now consider the definition of Tobin's average q

$$q_t = \frac{k_{1,t+1}\left(1-\frac{\mu_{1t}}{p_t}\right) + k_{2,t+1}\left(1-\frac{\mu_{2t}}{p_t}\right)}{k_{1,t}+k_{2,t}},$$

and note that if none of the irreversibility constraints bind both multipliers will equal zero. The law of motion of capital implies $k_{i,t+1} \geq (1-\delta)k_{i,t}$ for $i = 1, 2$, so that $q_t \geq (1-\delta)$. **Q.E.D.**

It is important to note that technological change would not have any impact on asset prices if capital were not assumed to be technology specific. Otherwise, agents could move all existing capital from the old technology to the new one, the irreversibility constraint would not bind, and Tobin's average q would not change as a result of the shock.

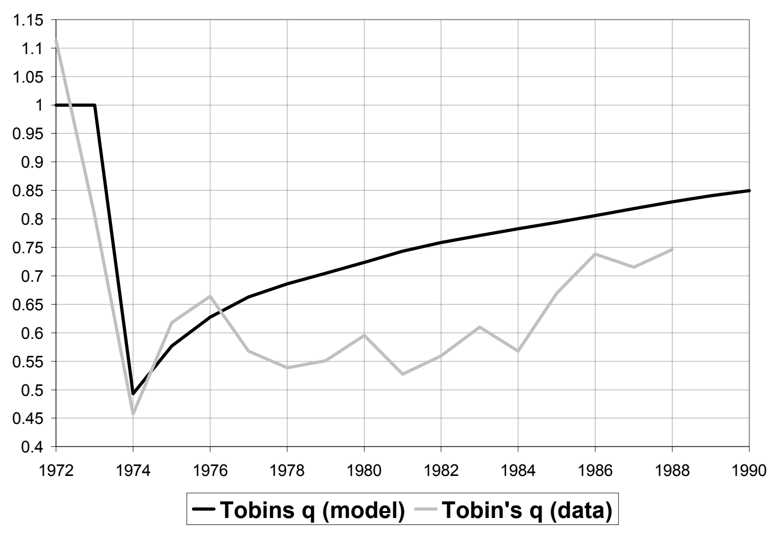
C. Testing the theory

I now analyze the quantitative aspects of this theory. For it I calibrate the model so that, in a balanced growth path[7], the share of income going to capital, the investment to capital ratio, and the capital output ratio match the corresponding 1950-72 averages of the U.S. data. Such procedure yields

$$\beta = 0.947, \lambda_0 = 0.4, \delta = 0.05.$$

I pick the initial productivity level of technology two, $A_{2,T}$, such that the drop in market values matches the observed one. The growth rate of $A_{2,t}$ is set equal to that of the old technology, i.e. $\frac{A_{2,t+1}}{A_{2,t}} = \gamma$. The model is tested in an indirect way by comparing the resulting GDP, consumption and investment series with their data counterparts.

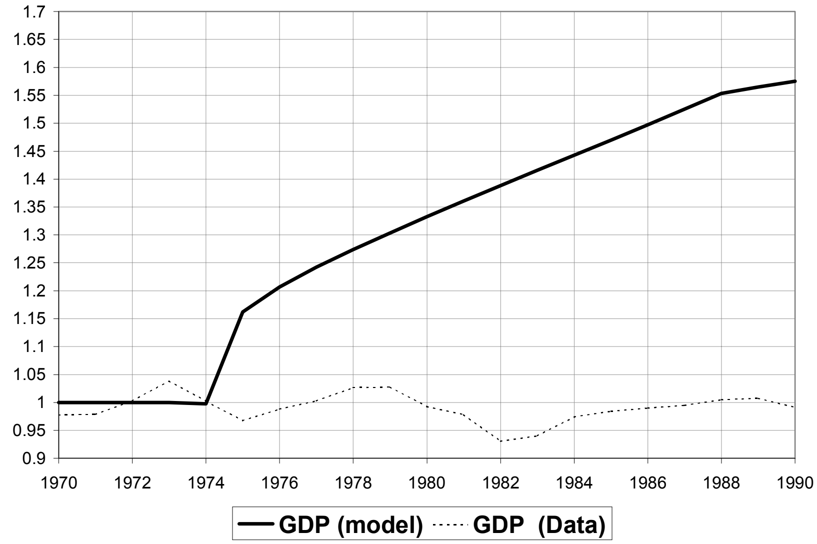
This model cannot be analytically solved. To obtain an approximate solution I followed Santos (1999) and set up an associated numerical model with piecewise linear interpolation, then I computed it using the value function iteration algorithm[8]. The following figures summarize the results. (GDP, consumption and investment are in per capita real units, detrended by a 2% growth rate[9], and normalized to 1 in 1972.)

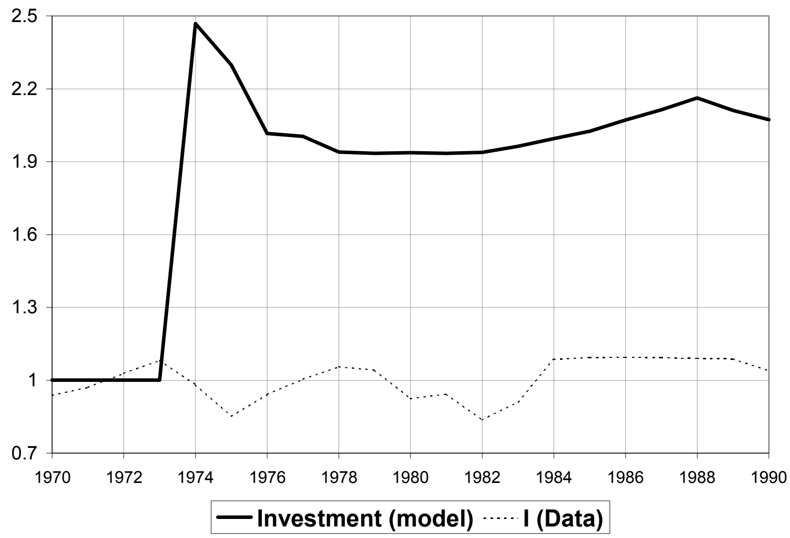


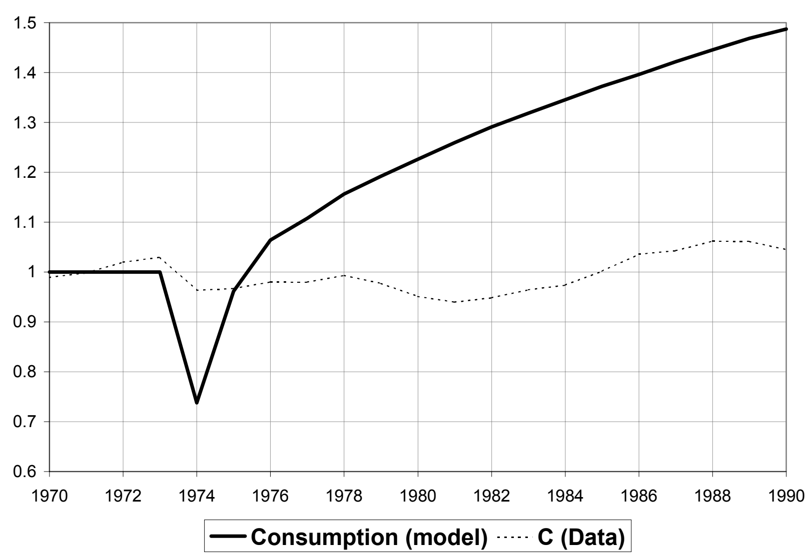
[7]The one that would arise when capital of type one is the only one available

[8]All code was written in Fortran 77. The associated constrained optimization problems were solved using routine DBCPOL from the IMSL math libraries. All programs can be downloaded from the author's web page at: www.econ.umn.edu/˜aperalta

[9]Under this detrending procedure a balanced growth equilibrium corresponds to a constant value for each of the corresponding aggregate quantities.


1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
GDP (model)
GDP (Data)


2.5
2.2
1.9
1.6
1.3
1
0.7
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Investment (model)
I (Data)


1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Consumption (model)
C (Data)

By construction, the initial drop in equity prices is equal to the one in the data. The technology shock does not affect in any way the productivity of the old technology but a new, better, technology becomes available. Not surprisingly, GDP grows faster than trend (that is at a rate higher than 2%) from the time of the shock, up to 1990, when it approaches its new balanced growth level.

When the shock hits there is no capital installed in the new technology but, as it is better than the existing one, agents have an incentive to increase their savings, in order to enjoy higher future consumption. Those are the patterns that one observes in the above figures. Yet, the initial value for A_{2T}, necessary for q to fall as much as in the data, is so big that investment doubles at the time of the shock. In the data investment did not change much around 1973-74 and, if anything, it slightly decreased. The quantitative implications of the model with respect to consumption are also inconsistent with the U.S. experience: consumption did not fall as much as the previous simulations indicate - minus 25% in 1974[10]-. The theory also predicts a strong expansion in consumption, just two periods after the shock, that cannot be found in the data.

In summary, shocks necessary for the model to deliver a big drop in q imply a strong economic expansion that is not consistent with the U.S. experience. More importantly, it is clear from the previous analysis that the better one wants the model to perform on the GDP consumption and investment side, the worse it will do on its asset pricing implications (a smaller drop in q would be obtained).

6. Bad news models: The productivity slowdown

One of the most prominent, "bad news," hypothesis for explaining the stock market collapse of 1974 is the one in Baily (1981). He argues that the abrupt increase in energy prices of 1974 made a substantial fraction of the capital stock obsolete. The value of existing capital decreased because it was not technologically suited to the new economic conditions. Wei (2001) quantifies this idea using a putty-clay general equilibrium model. In such an economy firms can determine, ex-ante, the capital-energy ratio of their production processes. Once capital is installed, the capital-energy ratio cannot be further adjusted. Her main result

[10] In fact, over the whole post-war period there has not been a period in which consumption falls by 25%

is that changes in energy prices cannot account for the observed decrease in equity prices. Specifically, she finds that an 80% increase in real energy prices causes the market value of existing capital to fall by only 2%.

I now evaluate an alternative type of bad news shock according to which it was the slowdown of the mid 1970's that made stock prices go down. To understand the basic economic forces linking economic growth to equity prices, consider the following version of Lucas (1978) asset pricing model. There is an infinitely lived representative agent with preferences ordered by

$$\sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}$$
$$0 < \beta < 1, \sigma > 0,$$

c_t denotes consumption at period t. Consumption is the output of the only durable good of this economy, a tree, and grows at a constant factor η. The price of a stock in this economy[11] equals the present discounted value of its expected future dividends, that is

$$P_t(\eta) = \sum_{j=1}^{\infty} \beta^j \frac{c_{t+j}^{-\sigma}}{c_t^{-\sigma}} c_{t+j} = c_t \frac{\beta\eta^{1-\sigma}}{1-\beta\eta^{1-\sigma}}.$$

Abstracting from changes in the stock of corporate capital, the above formula can be used to relate the market value of the corporate sector to the growth rate of the economy, $\eta - 1$. I take the total amount of corporate output going to capital[12] as an approximation to the flows of income generated by U.S. corporations, and its average growth factor as a measure for η.

Table 1 reports the percentage change in equity prices when the corporate sector passes, unexpectedly, from a high growth rate, η_H (the U.S. average over the 1960-72 period), to a

[11] I.e., the price of a claim to the future output flows generated by the tree

[12] Which equals gross product of corporate business minus compensation of employees (corporate). Both in real, per-capita units.

low one, η_L (the U.S. average over the 1973-1983 period), with

$$\eta_L = 1.02, \eta_H = 1.04, \text{ and } \beta = 0.96,$$

σ	1.1	0.9	0.8	0.7	0.5
Percentage change in Market value	9.35%	-9.35%	-18.76%	-28.22%	-47.29%

Table 1

If agents are not extremely risk averse, that is if $\sigma < 1$, the above "back of the envelope" calculation shows that the mid 1970's slowdown can account for a large fraction of the observed stock market collapse. If the coefficient of risk aversion σ is larger than one, then equity prices go up as a result of a slowdown. This is a well known result in the finance literature, and is due to the positive relation between interest rates and consumption growth imposed by the model. An economic slowdown implies a slowdown in the flows of dividends but, if $\sigma > 1$, the interest rate falls so much that their present value actually raises.

Determining whether the previous results carry over to a dynamic general equilibrium framework, where capital accumulation is permitted, is the main purpose of the following sections.

In a one sector neoclassical model the economy's growth rate is exogenously determined, by the growth rate of total factor productivity, and then seems like the natural place to start the analysis of the previous question. I feed such model with a TFP sequence that slows down unexpectedly, and obtain consistent predictions for the behavior of GDP, consumption and investment. What the neoclassical model of optimal growth cannot account for is the magnitude of the observed movements in Tobin's average q.

Standard asset pricing models, like the one of Lucas (1978), abstract from changes in capital stocks and attribute market value movements to changes in the price of capital. The one sector neoclassical model offers an extremely different explanation for stock market fluctuations. In it, the relative price of capital is fixed and thus, market values only change when capital stocks do. In the U.S. data, the correlation between the market value of corporate equity and the net stock of corporate capital, as ratios to GDP, is highly negative over the mid 1970's (-0.75). Thus, such model has no hope of explaining the observed patterns in q.

In section eight, I consider a simple model which allows for the relative price of capital to move as a result of a technology shock. I show that "bad news" imply an immediate drop in Tobin's average $q,$ and an economic slowdown consistent with the U.S. data. The main failure of this theory is that it cannot account for the most prominent feature of the data: the persistently low values of Tobin's average q.

7. Bad news in a one sector neoclassical model

To start the analysis of the bad news hypothesis, I use a version of the one sector neoclassical growth model, which is a particular case of the economy of section three. The problem of the consumer is,

$$\begin{aligned} & \max \sum_{t=0}^{\infty} \beta^t u(c_t) \\ & s.t. \\ \sum_{t=0}^{\infty} p_t \left\{ c_t + V_t(s_{t+1} - s_t) \right\} & \leq \sum_{t=0}^{\infty} p_t \left\{ d_t s_t + w_t n_t \right\} \\ s_t & \geq 0, \text{ given } s_0. \end{aligned}$$

Assume there is only one type of capital, and that investment decisions are reversible. The problem of the firm can then be written as

$$\begin{aligned} & \max \sum_{t=0t}^{\infty} p_t \left[k_t^{\alpha} \left(A_t n_t \right)^{1-\alpha} - w_t n_t - x_t \right] \\ & s.t. \\ & k_{t+1} = x_t + (1-\delta) k_t \\ & A_{t+1} = \eta A_t; \ \eta \geq 1 \\ & k_t \geq 0 \text{ for all } t \end{aligned}$$

Finally, the aggregate resource constraint is

$$x_t + c_t = k_t^{\alpha} \left(A_t n_t\right)^{1-\alpha}.$$

A. The productivity slowdown

Assume the economy had reached its balanced growth path by the time shock hits. The slowdown comes in period T, it is completely unexpected[13], and the growth rate of total factor productivity changes, permanently, from η^h to η^l, with $\eta^h > \eta^l$. By definition of a balanced growth path, a slowdown in TFP eventually translates into a slowdown in GDP, consumption and investment of the same proportion. Hence, this model can deliver patterns for aggregate quantities consistent with the data. What remains to be evaluated is the effect of bad news on equity prices.

B. Effects on q

As this is just a particular case of the economy of section three, proposition one can be applied. Investment decisions are reversible, and thus, for all t, and all η :

$$q = \frac{k_{t+1}}{k_t} = \eta_{k_t}.$$

where η_{k_t} is the equilibrium growth factor of capital at date t. Note that, in a balanced growth path, η_{kt} is equal to the growth factor of total factor productivity.

One can use the above formula to analyze what happens to q when the shock hits. In particular, the percentage change in q from period $T-1$ to period T equals

$$\frac{q_T}{q_{T-1}} = \frac{\eta_{k,T}}{\eta^h} - 1.$$

As there are no further shocks, $\eta_{k,T}$ goes asymptotically to its balanced growth rate η^l, and the shock delivers a permanent decrease in Tobin's q. Notice, though, that the quantitative impact of bad news on q is very small: If the economy passes from a growth rate of 3% to

[13] Assuming that the technology shock is completely unexpected is just a simplifying condition. The same type of qualitative results are obtained in a model in where TFP follows a Markov process (from the quantitative point of view similar results are obtained as long as the probability of a slowdown is small).

0% right after the shock (which is much more extreme than what occurred in the U.S. during the mid 1970's) the implied decrease in Tobin's q is only 3%.

C. A crucial distinction between a tree model and a model with capital accumulation

Why a slowdown translates in a dramatic fall in equity prices when one uses Lucas's model, but not in a one sector neoclassical growth model?. In both theories a sudden drop in the growth rate of the economy has a negative effect on equity prices, because the growth rate of dividends goes down. Yet, in a neoclassical model a slowdown also implies a decrease in the rate of investment, which increases the fraction of total output that can be paid to shareholders, and this pushes equity prices up. The relative price of capital is fixed at in a one sector model, thus the two effects must cancel out.

I now provide a balanced growth analysis that gives support to the previous ideas. In a model with production, dividends equal the share of income going to capital minus gross investment. Then,

$$V_\tau = \frac{1}{p_\tau}\sum_{t=\tau+1}^{\infty} p_t d_t = \sum_{t=\tau+1}^{\infty} p_t \left[\alpha k_t^\alpha (A_t n_t)^{1-\alpha} - x_t\right]$$

for all $\tau = 0, 1, 2, \ldots$. Solving for x_t in the law of motion for capital, and substituting its value in the above equation delivers

$$V_\tau = \frac{1}{p_\tau}\sum_{t=\tau+1}^{\infty} p_t \left[\alpha k_t^\alpha (A_t n_t)^{1-\alpha} + (1-\delta)k_t - k_{t+1}\right]$$

Let η be the exogenously given growth rate of total factor productivity, that is $\frac{A_{t+1}}{A_t} = \eta$. To simplify the analysis, assume that the economy has reached its balanced growth rate and all variables grow at rate $\eta - 1$. It follows that

$$V_\tau = \frac{1}{p_\tau}\sum_{t=\tau+1}^{\infty} p_t \left[\alpha k_t^\alpha (A_t n_t)^{1-\alpha} + (1-\delta-\eta)k_t\right] =$$

$$= \sum_{t=\tau+1}^{\infty} p_t \left[\alpha (k_\tau \eta^t)^\alpha (A_\tau \eta^t n_t)^{1-\alpha} + (1-\delta-\eta)k_\tau \eta^t\right] =$$

$$= \left[\alpha k_\tau^\alpha (A_\tau n_\tau)^{1-\alpha} + (1-\delta-\eta)k_\tau\right] \sum_{t=\tau+1}^{\infty} p_t \eta^t =$$

$$= \left[\alpha k_\tau^\alpha (A_\tau n_\tau)^{1-\alpha} + (1-\delta-\eta)k_\tau\right] \sum_{t=\tau+1}^{\infty} \left(\beta \eta^{1-\sigma}\right)^t =$$

$$= \left[\alpha k_\tau^\alpha (A_\tau n_\tau)^{1-\alpha} + (1-\delta-\eta)k_\tau\right] \frac{\beta \eta^{1-\sigma}}{1-\beta\eta^{1-\sigma}}.$$

The term between brackets denotes the fraction of total output that shareholders expect to receive, while the sum denotes the present value of a stream that grows at rate η. If the economy slows down unexpectedly, from a high growth rate $\eta_H - 1$ to a low one $\eta_L - 1$, and one assumes $\sigma < 1$, the term in the sum, which is the only one that appears in a "tree" model, goes down. In a model with capital accumulation, it also happens that firms lower their investment as a result of the shock, and the fraction of total output that can be paid to shareholders goes up. The production possibility frontier implies that capital and consumption can be interchanged in a one to one basis. Thus, in any competitive equilibrium, the relative price of capital is fixed at one and the two effects must cancel out.

For the equity prices to be affected by a technology shock, it is necessary to consider a model in which a fundamental distinction between capital and consumption goods is made, and in which more than two types of capital goods are available. The following section analyzes an economy with such properties.

8. Bad news in a stochastic two-sector model with many types of capital

Consider a world with two types of commodities: a single consumption good and an infinite sequence of different vintages of capital, indexed by $i = 0, 1, \ldots$. Capital is limited in how many generations of improvement can be sustained. Nevertheless the stage of improvement at which a capital stock is played out and can be improved no further is not known in advance[14]. The basic question I analyze is: what impact does the discovery that existing capital cannot be further improved has on its value?

[14] The model of this section follows closely the ideas of Boldrin and Levine (2001).

A. The state space

The state of technology, h_t, follows a Markov chain characterized by: a) the set of states possible at any given period, $H = \left\{\eta_g, \eta_b\right\}$; b) the transition probability matrix

$\pi(h'\|h)$	η_g	η_b
η_g	1-π	π
η_b	0	1

and c) a given initial state $h_0 = \eta_g$. A *state history* $h^t = (\eta_0, \eta_1, ..., \eta_t)$ is a finite collection of states from the first to the current period; it is well known that the above Markov chain induces a sequence of probability measures $\pi(h^t)$ on state histories via the recursion

$$\pi(h^t) = \pi(h_t|h_{t-1})\pi(h_{t-1}|h_{t-2})...\pi(h_1|h_0).$$

These probabilities will be useful in the determination of state contingent plans for the consumer, whose behavior is analyzed below.

B. Production possibilities

There are a countable number of *generations* of capital $i = ..., -1, 0, 1...$. I will denote by $k^{i(h^t)}$ the amount of capital of generation i available at period t, following the state history h^t, and by $\bar{\imath}(h^t)$ the highest generation of capital available at h^t. Production takes place through linear activities, each activity takes as input one unit of capital of a specific generation and produces a single output in the following period. One unit of capital of generation i may be used as the input into two different activities, each of which is characterized by the output obtained:

(1) γ^i units of consumption, $\gamma > 1$

(2) $\rho > 1$ units of the next generation of capital: generation $i + 1$

for all $i < \bar{\imath}(h^t)$.

The role of the technology shock is to determine whether capital of the highest generation can be upgraded or not. Thus, when $i = \bar{\imath}(h^t)$, one unit of $k^{\bar{\imath}(h^t)}$ can be used into two different activities whose output is

(1) $\gamma^{\bar{\imath}(h^t)}$ units of consumption for any $h_t \in H$;

(2) If the state is good ($h_t = \eta_g$): ρ units of the next generation of capital $\bar{\imath}(h^t) + 1$

If the state is bad ($h_t = \eta_b$): ρ units of capital of the same generation $\bar{\imath}(h^t)$

To keep the analysis simple I will assume that the initial vector of capitals, k_0^i, has one unit of capital of generation zero, and zero units of all other possible generations of capital. Given the above production activities, and k_0^i, one can see that, at any given state history h^t, the only generation of capital available for production is the highest one, $\bar{\imath}(h^t)$.

C. Competitive equilibrium

The problem of the household consists of finding the state-contingent consumption and asset holdings plans $\{c_t(h^t), s_{t+1}(h^t)\}_{t=0}^{\infty}$ that solve

$$\max E_0 \sum_{t=1}^{\infty} \beta^t \frac{c_t^{1-\sigma}}{1-\sigma}$$

$s.t.$

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

$$= \sum_{t=0}^{\infty} \sum_{h^t} p_t [d_t s_t]$$

$s_t \geq 0, \; s_0$ given;

where E_0 denotes the mathematical expectation conditional on information available at date 0. $V_t(h^t)$ is the price of a claim to the dividend stream, $\{d_t(h^t)\}_{t=1}^{\infty}$, and $s_{t+1}(h^t) - s_t$ denotes net share purchases in period t.

Firms hold the stock of capital and take investment decisions in order to maximize the present value of dividends, namely

$$\max \sum_{t=0}^{\infty} \sum_{h^t} p_t(h^t) \left[\gamma^{i(h^t)} \cdot \left(k_t^{i(h^t)} - x_t^{i(h^t)}\right)\right] \quad (9)$$

$s.t.$

$$k_{t+1}^{i'} = \rho x_t^{i(h^t)} \quad (10)$$

$$i' = i(h^t) + 1 \text{ if } h_t = \eta_g$$

$$i' = i(h^t) + 1 \text{ if } h_t = \eta_b$$

$$k_t^{i(h^t)} \geq 0$$

$$c_0, k_0 \text{ given}$$

An Arrow-Debreu competitive equilibrium for this economy consists of sequences of state-contingent prices, $\{p_t(h^t), V_t(h^t)\}_{t=0}^{\infty}$, and allocations, $\{s_t(h^t), c_t(h^t), x_t(h^t), k_t^i(h^t)\}_{t=0}^{\infty}$, such that

1. Given prices, $\{s_t(h^t), c_t(h^t)\}$ solve the consumer's problem,
2. Given prices, $\{x_t(h^t), k_t^i(h^t)\}$ solve the firm's problem and
3. Aggregate feasibility is satisfied

$$c_{t+1}(h^t) = \gamma^i \lambda(h^t) k_t^{i(h^t)}$$

$$k_{t+1}^{i'} = \rho(1 - \lambda(h^t))) k_t^{i(h^t)}$$

$$i' = i(h^t) + 1 \text{ if } h_t = \eta_g$$

$$i' = i(h^t) \text{ if } h_t = \eta_b$$

$$s_t(h^t) = 1$$

$$0 \leq \lambda(h^t) \leq 1, \text{ for all } h^t \text{ and } t = 0, 1, \dots .$$

It is well known, given the Markovian structure of the technology shock, the time invariant properties of the objective functions and constraints of both, the consumer's and the firm's problem, that, in a competitive equilibrium, prices and allocations will also have the Markov property.

D. Efficiency of equilibria and the planner's problem

A complete proof of the Second Welfare theorem for this type of economies can be found in Boldrin and Levine (2001). It follows that the solutions to the planner's problem, written in its recursive form as,

$$W(k,i,\eta) = \beta \max \left[\frac{c^{1-\sigma}}{1-\sigma} + E_\eta W(k',i',\eta') \right] \quad (11)$$

$$\begin{aligned} s.t. \\ c &= \gamma^i \lambda(\eta) k^i \\ k' &= \rho(1-\lambda(\eta))k^i \qquad (12) \\ i'(\eta_g) &= i+1 \\ i'(\eta_b) &= i \\ 0 \leq \lambda&(\eta) \leq 1 \end{aligned}$$

can be supported as a competitive equilibrium.

The above technology correspondence is a convex cone and the one period utility u is homogeneous of degree $(1-\sigma)$. Thus, the value function W is homogeneous of degree $(1-\sigma)$ with respect to k. Also, notice that having k^i units of vintage i capital results in $\gamma^i k^i$ times as much consumption in every future time, and state, as with a single unit of generation 0 capital. Hence,

$$W(k,i,\eta) = \left(\gamma^i k\right)^{1-\sigma} W(1,0,\eta).$$

The above facts reduce the planner's problem from the functional equation in (11), to that of finding the four real numbers $W(1,i,\eta_g), W(1,i,\eta_b)$, $\lambda(\eta_g)$ and $\lambda(\eta_b)$ that solve

$$\begin{aligned} W(1,i,\eta_g) = \beta \max_{\lambda(\eta_g)} [&\frac{(\lambda(\eta_g)\gamma^i)^{1-\sigma}}{1-\sigma} + \\ &+ (1-\pi)\left(\gamma\rho(1-\lambda(\eta_g))\right)^{1-\sigma} W(1,i,\eta_g) + \\ &+ (\pi)\left(\rho(1-\lambda(\eta_b)\right))^{1-\sigma} W(1,i,\eta_b)] \end{aligned}$$

and

$$W(1,i,\eta_b) = \beta \max_{\lambda(\eta_b)} [\frac{(\lambda(\eta_b)\gamma^i)^{1-\sigma}}{1-\sigma} +$$

$$+ \left(\rho(1-\lambda(\eta_b))\right)^{1-\sigma} W(1,i,\eta_b)].$$

At this point it is crucial to highlight the timing of events that the above model implicitly assumes. In particular note that capital is produced in period t before the state in period t is known, but is used in period t after the state is determined. Consequently, it is possible to compare the value of capital immediately before and immediately after the state is realized. As the following result shows, the model allows for the relative price of installed capital to change when "bad news" arrive. At least initially, equity prices behave in the same way as in the Lucas' Tree model of section 6.

PROPOSITION 3. *If $0 < \sigma < 1$, news of a negative shock causes the value of the capital stock to fall immediately; if $\sigma > 1$ the value of the capital stock rises immediately. Moreover, for π small, the percentage change in equity prices when the state changes from good to bad is well approximated by*

$$\frac{W(1,0,\eta_b)}{W(1,0,\eta_g)} - 1$$

Proof. Since, at the beginning of period t both, the stock of capital and current consumption are fixed, the only question is what happens to the price of capital. If there is not a negative shock in the current period its value will be

$$\left(\gamma^{i(h^t)} k^{i(h^t)}\right)^{1-\sigma} W(1,0,\eta_g)$$

if there is a negative shock the value will be

$$\left(\gamma^{i(h^t)} k^{i(h^t)}\right)^{1-\sigma} W(1,0,\eta_g).$$

The corresponding prices at which capital is traded are determined by differentiating these values with respect to $k^{i(h^t)}$. Consequently, the price of capital when the state is good is proportional to $(1-\sigma)W(1,0,\eta_g)$, and when the state is bad to $(1-\sigma)W(1,0,\eta_b)$. It is clear that $W(1,0,\eta_b) < W(1,0,\eta_g)$, hence, when $0 < \sigma < 1$ one has $(1-\sigma)W(1,0,\eta_b) < (1-\sigma)W(1,0,\eta_g)$, and equity prices fall as a result of the bad shock, while if $\sigma > 1$ this means that $(1-\sigma)W(1,0,\eta_b) > (1-\sigma)W(1,0,\eta_g)$, so that equity prices go up as a result of the bad shock. These observations prove the first part of the proposition.

Observe that the price of capital following η_g, but before knowing what the following state is, is given by (1-σ)$\gamma^{i(h^t)}[(1-\pi)\left(\gamma^{i(h^t)}k^{i(h^t)}\right)^{-\sigma} W(1,0,\eta_g)+\pi\left(\gamma^{i(h^t)}k^{i(h^t)}\right)^{-\sigma} W(1,0,\eta_b)]$. On the other hand, the price of capital after learning the state has switched to η_b is just (1-σ)$\gamma^{i(h^t)}\left(\gamma^{i(h^t)}k^{i(h^t)}\right)^{-\sigma} W(1,0,\eta_b)$. This allows to compute the percentage change in equity prices when the economy switches from the good to the bad state as

$$\frac{1}{(1-\pi)\frac{W(1,0,\eta_g)}{W(1,0,\eta_b)}+\pi}-1=\frac{(1-\pi)\left(1-\frac{W(1,0,\eta_g)}{W(1,0,\eta_b)}\right)}{(1-\pi)\frac{W(1,0,\eta_g)}{W(1,0,\eta_b)}+\pi}=$$

$$=\frac{(1-\pi)\left[W(1,0,\eta_b)-W(1,0,\eta_g)\right]}{(1-\pi)W(1,0,\eta_g)+\pi W(1,0,\eta_b)}.$$

Finally, as $\pi \longrightarrow 0$ the above ratio equals

$$\frac{W(1,0,\eta_b)}{W(1,0,\eta_g)}-1,$$

proving the second part of the proposition. **Q.E.D.**

E. A numerical experiment

To get an idea of the quantitative aspects of the model, consider the following parameterization: The probability of the bad state is $\pi = 0.0001$, the discount factor is $\beta = 0.98$ and ρ and γ are chosen so that the growth rate of consumption when the state is good is three percent (which corresponds to the U.S. average over the 1950-72 period), and two percent when the bad state comes (which corresponds to the U.S. average over the 1974-84 period).

The following table shows the percentage changes in the market value of capital as the economy passes from the good to the bad state, as a function of the risk aversion parameter σ

σ	1.1	0.9	0.8	0.7	0.5
Percentage change in Market value	4.40%	-5.84%	-9.60%	-14.65%	-27.00%
Interest rate (good state)	7.80%	6.60%	5.60%	5.00%	3.84%
Interest rate (bad state)	6.60%	5.50%	5.00%	4.50%	3.50%

F. Tobin's q

The previous numerical experiment shows the model is capable of generating a big drop in equity prices as a result of an economic slowdown. The main failure of this theory is that it cannot account for the persistency in the low values of q, which is the most prominent feature of the data. In equilibrium, the value of q jumps to $\frac{1-\lambda(\eta_b)}{1-\lambda(\eta_g)}$ just one period after the shock, and, two periods afterwards, it reaches its new steady state value $(1-\lambda(\eta_b))$. In the above numerical experiments, the arrival of a permanent economic slowdown implies a permanent decrease in Tobin's q of, at most, one per-cent.

The reason for the failure of the model is that, as in the neoclassical model of exogenous technological progress, the market value of the representative firm is proportional to the replacement value of its capital stock. These ideas are formalized in the following result

Proposition 4. *In any competitive equilibrium*

$$V_t(h^t) = \frac{\gamma^i}{\rho} k_{t+1}^{i(\eta)} = \frac{\gamma^i}{\rho}\left(1-\lambda(h^t)\right) k_t^i.$$

So that, Tobin's average q is determined by

$$q(h^t) = 1-\lambda(h^t) \text{ for all state histories } h^t.$$

Proof. The first order condition of the household's problem, with respect to s_{t+1}, delivers

$$\begin{aligned} p_t V_t = {} & p_{t+1}(\eta_g)\left[V_{t+1}(\eta_g) + d_{t+1}(\eta_g)\right] \quad (13) \\ & + p_{t+1}(\eta_b)\left[V_{t+1}(\eta_b) + d_{t+1}(\eta_b)\right]. \end{aligned}$$

On the other hand, if one solves for x_t in (10) and substitutes this value into the objective function of the firm - equation (9) - the first order condition of the firm's problem with respect to $k_{t+1}^{i(\eta)}$ implies

$$p_t \frac{\gamma^i}{\rho} = p_{t+1}(\eta_g)\gamma^{i+1} + p_{t+1}(\eta_b)\gamma^{i+1}. \tag{14}$$

Consider the definition of period $t+1$ dividends,

$$\begin{aligned} & p_{t+1}(\eta_g)d_{t+1}(\eta_g) + p_{t+1}(\eta_b)d_{t+1}(\eta_b) \quad (15) \\ & = p_{t+1}(\eta_g)\gamma^{i+1}\left(k_{t+1}^{i+1} - \frac{k_{t+2}^{i+2}(\eta_g)}{\rho}\right) \\ & + p_{t+1}(\eta_b)\gamma^{i+1}\left(k_{t+1}^{i+1} - \frac{k_{t+2}^{i+1}(\eta_b)}{\rho}\right). \end{aligned}$$

Multiply both sides of (14) by k_{t+1}^{i+1} and use (15) to get

$$\begin{aligned} & p_{t+1}(\eta_g)\left[d_{t+1}(\eta_g) + \frac{\gamma^{i+1}k_{t+2}^{i+2}(\eta_g)}{\rho}\right] + p_{t+1}(\eta_b)\left[d_{t+1}(\eta_b) + \frac{\gamma^{i+1}k_{t+2}^{i+1}(\eta_b)}{\rho}\right] \quad (16) \\ & = p_t \frac{\gamma^i}{\rho} k_{t+1}^{i+1} \end{aligned}$$

finally, (13), (16) and the transversality conditions for the problem of the firm, and the one for the consumer, renders

$$V_t(h^t) = \frac{\gamma^{i(h^t)}}{\rho} k_{t+1}^{i(h^t)} = \frac{\gamma^i}{\rho}\left(1 - \lambda(h^t)\right) k_t^i.$$

In equilibrium the relative price of a new unit of capital of generation i equals $\frac{\gamma^i}{\rho}$, hence, the definition of Tobin's q gives

$$q(h^t) = \frac{V(h^t)}{\frac{\gamma^i}{\rho}k_t^i} = 1 - \lambda(h^t).$$

Q.E.D.

9. Conclusions and guidelines for further research

This study employs dynamic general equilibrium models to quantitatively test the idea that technical change caused the stock market collapse of the mid 1970's, its subsequent stagnation, and recovery. First, I considered the idea that "good news," in particular the information technology revolution, was behind these trends. A calibrated version of the model with technology specific capital and irreversible investment, showed that news about the *future* availability of a better technology does not have any effect on the price of installed capital, and that, in general, such a hypothesis cannot deliver a consistent explanation for the observed patterns of equity prices and aggregate capital. Then, I assessed another type of "good news" shock, according to which the *actual arrival* of a better technology was the cause of the stock market collapse of 1974, and of its subsequent recovery. In this case, the model can make the price of old capital fall as much as in the data, but it must imply a two-fold increase in investment, and a strong economic expansion right at the time when the U.S. economy slowed down.

I then evaluated the hypothesis that "bad news," specifically the economic slowdown of the mid 1970's, caused the observed collapse and stagnation of equity prices. The one-sector neoclassical growth model does a good job in accounting for the movements in aggregate quantities but forces the relative price of installed capital to equal one. To understand how the price of capital moves as a result of technological change, one has to consider an economy with many types of capital and must distinguish investment from consumption goods. This study analyzes an economy with such properties, and finds an unexpected slowdown can cause a substantial drop in market values, provided that agents are not extremely risk averse. What this class of models cannot account for is the long stagnation in Tobin's average q that characterizes the data.

This analysis shows that the most important hypotheses, based on technological change, for explaining the observed patterns of U.S. equity markets fail, either from the quantitative point of view, the qualitative one, or both. Yet, some clear guidelines for future research can be extracted from the very same analysis. Each existing theory captures some feature of the U.S. data: On the one hand, a model with capital irreversibility can deliver a large and persistent drop in Tobin's average q, but gives counterfactual predictions for all aggregate quantities. On the other hand, "bad news", in a model with many types of capital, yields the right predictions for the behavior of GDP, consumption and investment, but fails in accounting for the movements of q. What is needed is a model that can account, simultaneously, for the observed patterns of the stock market, and for those of aggregate quantities like GDP, investment and consumption.[15]

My results reinforce the view that any general equilibrium theory of stock market fluctuations must "necessarily stem from a model in which 'frictions' are present that prevent the price of existing capital from being driven equal at all times to the price of newly produced capital."[16] Theory shows that for such frictions to have any *equilibrium* effects on asset prices, it is necessary that agents find, suddenly, a better place to allocate all investment resources. Therefore, some form of "good news" shock appears to be essential for the construction of a successful model.

Finally, from the quantitative analysis in this paper, one can see that the main challenge for any general equilibrium theory of equity price movements resides in reconciling the observed patterns of Tobin's average q with those of aggregate investment. The lower the values of q that one demands from the model, the better the new technology has to be, and the larger the jump in investment that the model may deliver. Constructing credible ways for overcoming this problem constitutes a further source of future research.

[15]In this sense, this paper extends a similar conclusion reached by Boldrin and Peralta-Alva (2002) to a much broader set of general equilibrium models for capital asset pricing.

[16]Using the words of Sargent (1980), page 1.

Appendix 1

Lemma 1. Under all of the assumptions outlined in section four, if news arrive at date 0 that a new, better, technology will become available at the beginning of period T, one has

$$q_t = (1 - \frac{\mu_t}{p_t})\frac{k_{1,t+1}}{k_{1,t}}, \text{ for all } t < T.$$

Proof. Notice that equations (3), (4) and (5) are some of the first order conditions of the problem of the firm, and the consumer, for all periods $0 \leq t < T$. Hence, for all $t < T$ one can still get

$$p_t V_t - p_{t+1} V_{t+1} = (p_t - \mu_t) k_{1,t+1} - (p_{t+1} - \mu_{t+1}) k_{1,t+2}.$$

The transversality condition of the consumer does not depend on the particular time period one is considering so that

$$(17) \quad p_t V_t = \lim_{\tau \to \infty} \left\{ \sum_{i=t+1}^{\tau} p_i d_i + p_\tau V_\tau \right\} = \sum_{i=t+1}^{\infty} p_i d_i.$$

Relative to the situation considered by proposition one, equations (5) and (8) have to be changed to take into account the future availability of capital of type two. Consider now all periods in which both types of capital are available. The first order conditions of the firm's problem with respect to $k_{1t+1}, k_{2t+1}, x_{1t}, x_{2t}$ can be used to derive

$$\begin{aligned}(p_t - \mu_t)\, k_{1,t+1} + (p_t - \mu_{2t}) k_{2,t+1} = {} & (p_{t+1} - \mu_{t+1}) k_{1,t+2} + \\ & (p_{t+1} - \mu_{2t+1}) k_{2,t+2} + p_{t+1} d_{t+1},\end{aligned} \quad (18)$$

where μ_{2t} denotes the multiplier associated to the irreversibility constraint for capital of type two. Using this, and the first order condition of the consumer (3), yields

$$\begin{aligned}p_t V_t - p_{t+1} V_{t+1} = {} & (p_t - \mu_t) k_{1,t+1} + (p_t - \mu_{2t}) k_{2,t+1} \\ & - (p_{t+1} - \mu_{t+1}) k_{1,t+2} - (p_{t+1} - \mu_{2t+1}) k_{2,t+2}.\end{aligned}$$

Finally, using (17) one gets

$$(p_t - \mu_t)k_{1,t+1} = \lim_{\tau\to\infty}\{\sum_{i=t}^{\tau} p_i d_i + (p_\tau - \mu_\tau)\, k_{1,\tau+1} +$$

$$+ (p_\tau - \mu_{2\tau})k_{2,\tau+1}\}$$

which, by the transversality condition of the problem of the firm, renders

$$(p_t - \mu_t)\, k_{1,t+1} = \sum_{i=t+1}^{\infty} p_i d_i,$$

and thus

$$V_t = (1 - \frac{\mu_t}{p_t})k_{1,t+1}$$

for all $t < T$. The above expression and the definition of Tobin's q yield the desired result

$$q_t = \frac{V_t}{k_{1,t}} = (1 - \frac{\mu_t}{p_t})\frac{k_{1,t+1}}{k_{1,t}} \geq (1 - \frac{\mu_t}{p_t})(1 - \delta).$$

Q.E.D.

Appendix 2

I now consider some standard functional forms for F and u to study the effects of "good news" on equity prices, and other aggregate variables. The shock comes in period 0 when agents learn that

$$
\begin{aligned}
F(k_{1t}, k_{2t}, n) &= k_{1t}^{\lambda_0}(A_{1t}n_{1t})^{1-\lambda_0} \text{ for } 0 \leq t < T \\
F(k_{1t}, k_{2t}, n) &= k_{1t}^{\lambda_0}(A_{1t}n_{1t})^{1-\lambda_0} + k_{2t}^{\lambda_0}(A_{2t}n_{2t})^{1-\lambda_0} \text{ for } t \geq T \\
k_{1t+1} &= x_{1t} + (1-\delta)k_{1t} \\
k_{2t+1} &= x_{2t} + (1-\delta)k_{2t}, \text{ with} \\
x_{2t} &= 0 \text{ if } t < T \\
x_{1t}, x_{2t} &\geq 0.
\end{aligned}
$$

Moreover,

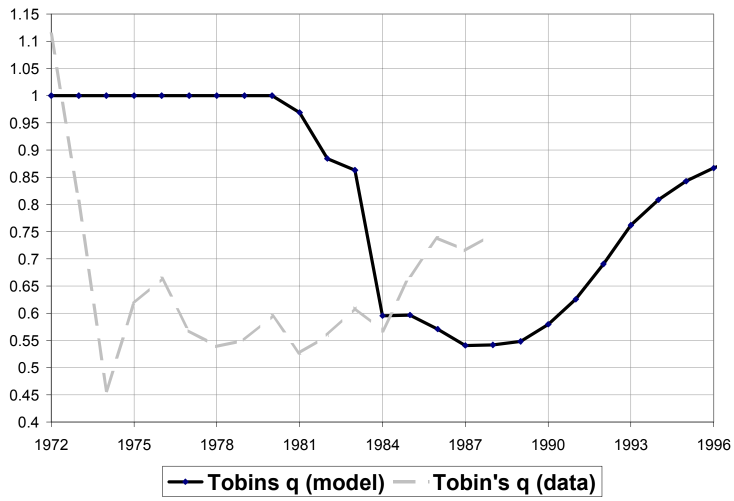
$$
\begin{aligned}
\frac{A_{2t+1}}{A_{2t}} &> \frac{A_{1t+1}}{A_{1t}} \text{ for } T \leq t < T+M \\
\frac{A_{2t+1}}{A_{2t}} &= \frac{A_{1t+1}}{A_{1t}} \text{ for } t \geq T+M
\end{aligned}
$$

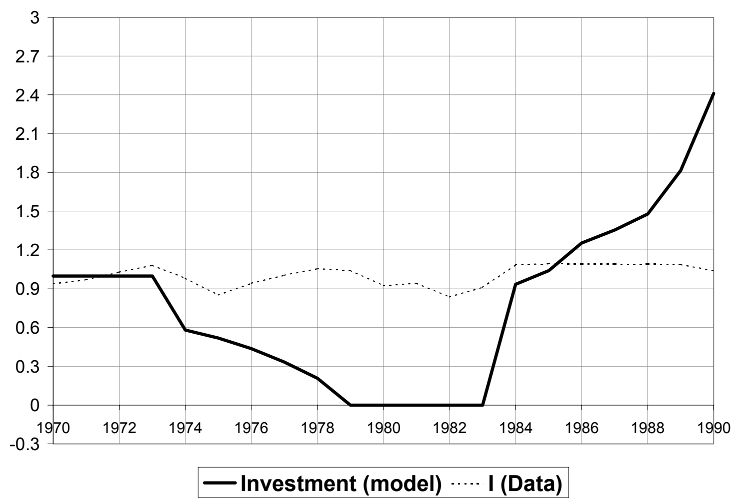
with $A_{2T} \leq A_{1T}$ and $A_{2T+M} > A_{1T+M}$.

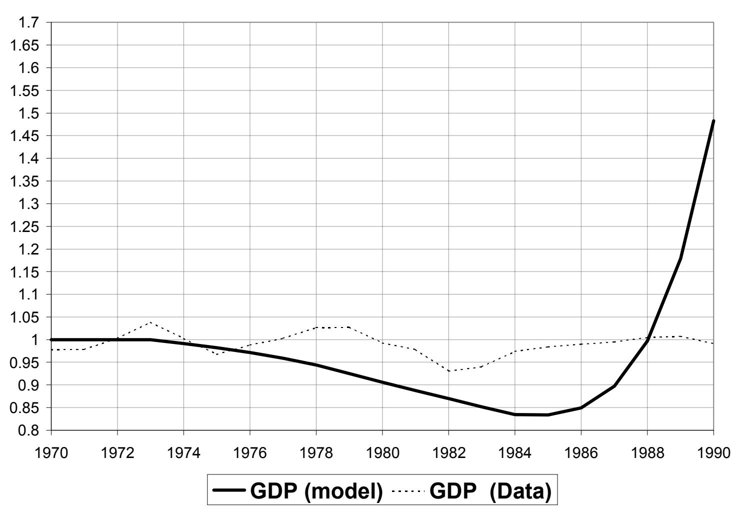
The new technology may start with a TFP level lower than the old one, but it has M periods over which its TFP grows faster than that of the old one; by period $T+M$ its TFP level is higher than that of the old one.[17]

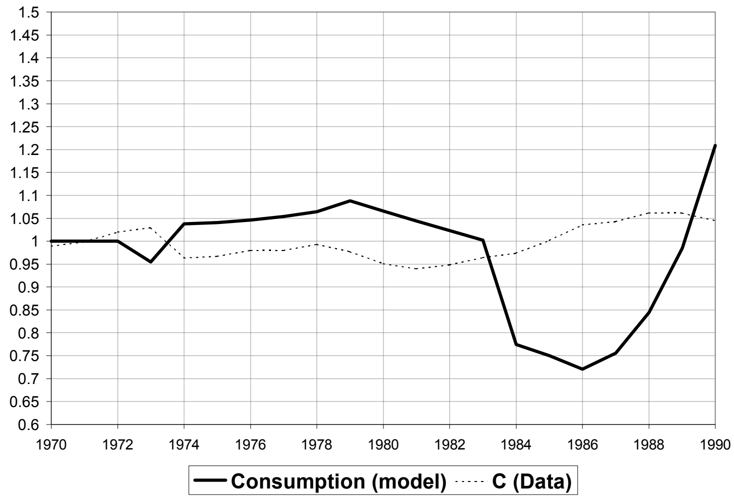
In the following simulations $T = 12$, $\lambda_0 = 0.4$ and $u(c) = \ln(c)$. The growth rate of A_{2t} and its terminal level are chosen so that the maximal drop in q that the model generates is big (in this case 40%). All data shown in the following graphs is in per capita real units and was detrended by a 2% growing series

[17] To simplify the analisys I assumed that, after period $T+M$, the new technology's TFP grows at the same rate as that of the existing one. This allows to write the model in its deviations from trend form, where the trend is time independent, which greatly simplifies the numerical simulations.


1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
1972
1975
1978
1981
1984
1987
1990
1993
1996
Tobins q (model)
Tobin's q (data)


3
2.7
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
0
-0.3
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
Investment (model)
I (Data)


1.7
1.65
1.6
1.55
1.5
1.45
1.4
1.35
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
1970
1972
1974
1976
1978
1980
1982
1984
1986
1988
1990
GDP (model)
GDP (Data)



This simulations show that the reception of "good news" has no immediate effects on Tobin's q. Investment starts decreasing right after the news are received but, as the old technology is the only one available for producing consumption, it does not decrease all the way to zero. In the above experiments, the irreversibility constraint becomes binding only when the new technology is available (1983) and, as predicted by the theory, it is then that q falls below one.

Then, at least under the functional forms considered in this experiment, learning that the IT-revolution was on the horizon cannot explain the stock market collapse of the mid 1970's. More importantly, the productivity level that the new technology must have (or agents were expecting it to have) for the model to generate a large decrease in q is "too high" to be consistent with other aggregate variables like GDP, consumption and investment.

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