Stock market boom and the productivity gains of the 1990s

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Abstract

Together with a sense of entering a New Economy, the US experienced in the second half of the 1990s an economic expansion, a stock market boom, a financing boom for new firms and productivity gains. This article proposes an interpretation of these events within a general equilibrium model with financial frictions and decreasing returns to scale in production. We show that the mere prospect of high future productivity growth can generate sizable gains in current productivity, as well as the other above mentioned events.

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1. Introduction

During the second half of the 1990s, the United States experienced the continuation of one of the longest economic expansions. The distinguishing characteristics of this period can be summarized as follows.

1. High growth rates of output, employment, investment and wages.
2. High growth rates of labor productivity.
3. A stock market boom.
4. A financing boom for new and expanding firms.
5. A sense of moving towards a "New Economy".

This article proposes an interpretation of these events where the prospect of a New Economy plays a key role in generating the other events. More specifically, it shows that the mere prospect of high future productivity growth can generate a stock market boom, a financing boom for new firms, an economic expansion as well as sizable gains in current productivity of labor. There are two main ingredients to our story: financing constraints due to limited contract enforceability, and firm-level diminishing returns to scale. Financing constraints generate an endogenous size distribution of firms. Diminishing returns make aggregate productivity dependent on the size distribution of firms.

A general equilibrium model is developed in which investment projects are carried out by individual entrepreneurs and financed through optimal contracts with investors. The structure of the contract is complicated by limited enforceability similar to Marcet and Marimon (1992), Kehoe and Levine (1993), Alvarez and Jermann (2000). The limited enforceability of contracts implies that new investment projects are initially small, but then increase gradually until they reach the optimal scale. This class of models has shown to be able to explain several important features of the firm dynamics. See Albuquerque and Hopenhayn (2004), Cooley, Marimon & Quadrini (2004), Quintin (2000) and Monge (2001).

In our model, an initial improvement in the prospects for future productivity growth generates the following set of reactions. First, the market value of firms is driven up by the increase in the expected discounted value of profits. Because of the higher market value, new firms find their financing constraints relaxed and are able to operate with a higher initial capital investment and employment. At the aggregate level, the increase in labor demand from the new firms pushes up the wage rate and forces existing unconstrained firms to adjust their production plans to increase the marginal productivity of labor. Therefore, while newer and smaller firms expand their employment, older and larger firms contract over time. This generates a more concentrated economy-wide size distribution of firms. Given the concavity of the production function, the more concentrated firm-size distribution leads to higher aggregate productivity of labor. This "reallocation effect" is in addition to the increase in productivity due to capital deepening. A reasonably calibrated model can generate a cumulative productivity gain of about 2.3 percent over a five year period, with about half attributable to the reallocation effect and the other half to capital deepening. This productivity gain is driven solely by the prospects of higher productivity growth.

To keep the analysis focused, we abstract from other channels emphasized in the literature through which expectations may have an immediate impact on current economic activity such as time-to-build, capital adjustment costs, or consumption smoothing. It should also be clear that we do not believe that the economic expansion experienced by the U.S. economy during the second half of the 1990s was entirely driven by expectations of future higher productivity growth. Rather, our explanation should be seen as complementary to others mechanisms emphasized in the literature that, for simplicity, are omitted from the analysis.[1]

The plan of the article is as follows. Section 2. reviews some of the events experienced by the U.S. economy in the 1990s. Section 3. presents the model, and Sections 4. and 5. characterize the equilibrium. Section 6. contains the quantitative analysis. Section 7. discusses key mechanisms underlying the results. Section 8. concludes.

2. Facts about the 1990s

This section contains details about some of the characteristics of the U.S. economy in the second half of the 1990s mentioned in the introduction.

2.1. Productivity growth

Baily (2002) surveys three of the most widely noticed studies that estimate the sources of productivity growth during the second half of the 1990s. As a summary, Table 1 reports averages across these three sets of estimates, namely, updated numbers from Oliner and Sichel (2000), the Economic Report of the President (2001) and Jorgenson, Ho & Stiroh (2002). These numbers incorporate the downward revision of GDP made in the summer of 2001.

[Place Table 1 here]

Output per hour in the nonfarm private business sector has grown at an annual rate of 2.55% during the period 1995-00 compared to a 1.40% growth rate during the period 1973–95. Therefore, there has been an acceleration of 1.15%. Abstracting from labor quality, which counts for a small decline (-0.01%), the table decomposes this acceleration in three components. The first component is the growth in multifactor productivity (MFP) in the computer sector. The estimate for this is 0.31%. Capital deepening, which results from the investment boom especially in computer equipment, counts for 0.43%. The remaining 0.42% is the structural acceleration in multifactor productivity outside the computer-producing sector. Our analysis

[1] For related papers that have considered different aspects of the relationship between stock markets and economic activity see, for instance, Caballero and Hammour (2002), Cooley and Yorukoglu (2001),and Beaudry and Portier (2004).

will focus on the last two components which accounted for somewhat over 4% of cumulative growth during the period 1995-00.[2]

2.2. Stock market boom

Figure 1 plots the productivity growth and the price-earning ratio in the post-war period. The post-war period can be divided in three sub periods: the "golden age" of rapid productivity growth between 1950:2 and 1972:2, the "slow down period" from 1972:2 to 1995:5, and the "revival period" since 1995:4. The identification and labelling of these sub-periods are taken from Gordon (2002).

[Place Figure 1 here]

Clearly, there is a strong positive association between productivity growth and price-earnings ratios.[3] Although the causal relationship can go in both directions, this article will emphasize the channel going from asset prices to labor productivity.

2.3. Financing boom for new firms

The dramatic expansion of the venture capital market is one piece of evidence for the financing boom of new firms during the second half of the 1990s. At the beginning of 2000, the size of the venture capital market has reached dimensions of macroeconomic significance. Although these funds were only about 1 percent of GDP, in terms of net private domestic investment they reached about 15 percent. Moreover, the funds injected through venture capital are only part of the funds raised and invested by these firms. Some of these firms, in fact, raise funds through IPOs which has also increased during the 1990s.

Another piece of evidence of this financing boom is given by the increased size of newly listed firms. According to Fama and French (2002), the average market value of a newly listed firm has increased relative to the market value of an incumbent (publicly listed) firm. As shown in Table 2, during the 1990s, the market value of a new firm listed in the New York Stock Exchange was on average equivalent to the market value of a firm located at the 17.5 percentile of incumbent firms. During the 1980s, in contrast, the average value of newly listed firms was located at the 8.2 percentile. A similar pattern can be observed for new listings in local exchanges. As discussed below, this greater size of new firms will be a key feature of our story.

[Place Table 2 here]

[2] Several studies (see for example Brynjolfsson and Hitt (2000), Jorgenson and Stiroh (2000), Oliner and Sichel (2000)), interpret the increase in multifactor productivity outside the computers sector as the result of the network and externality advantages brought about by information and communication technologies. At the same time, the increase in investment and the subsequent capital deepening was driven by the fall in prices of computers. This article provides an additional explanation for the improvement in multifactor productivity and capital deepening.

[3] Because the subdivision in the three sub-periods is to some extent arbitrary, we have also computed the trends of these two series using a low-pass filter. The pattern of these trends displays a similar picture.

2.4. "New Economy"

While more elusive, the sense of moving towards a New Economy has been manifest in many ways. Shiller (2000) contains a detailed account of this tendency linked, among other things, to the emergence of the internet and the ever wider use of computer technology. Fed chairman Mr. Greenspan has been making the case for an upward shift in trend productivity growth driven by new equipment and management techniques since 1995. See, for example, Ip and Schlesinger (2001). The same article also describes how this view spread across the Federal Open Market Committee. Referring to a speech of Fed member Mr. Meyer, the article reports:

> "'*we can confidently say ... that, since 1995, actual productivity growth has increased.' At the time he suggested that he believed the economy could annually grow by overall as much as 3% without inciting inflation, up from his longtime prior estimate of a 2.5% limit. Soon, thereafter, he indicated that perhaps the right number was 3.5% to 4%.*"

The goal of this article is to link these events in a unified framework. The driving force in our analysis will be the expectations of a New Economy.

3. The model

This section contains a description of the elements of our model and outlines their contributions to the main results.

3.1. Agents and preferences

The economy is populated by a continuum of agents of total mass 1. In each period, a fraction $1-\alpha$ of them is replaced by newborn agents. Therefore, α is the survival probability. A fraction e of the newborn agents have an investment project and, if they get financing, they become entrepreneurs. The remaining fraction, $1-e$, become workers. Agents maximize:

$$E_0 \sum_{t=0}^{\infty} \left(\frac{\alpha}{1+r}\right)^t \Big(c_t - \varphi_t(h_t)\Big) \tag{1}$$

where r is the intertemporal discount rate, c_t is consumption, h_t are working hours, $\varphi_t(h_t)$ is the disutility from working. The function φ_t is strictly convex and satisfies $\varphi_t(0) = 0$. The time dependence of this function is assumed to guarantee a balanced growth path as specified below. The assumption of consumption risk neutrality is made for tractability reasons as it is standard in the financial contracting literature. We will discuss below the extent to which this affects our conclusions.

Given the assumption of risk neutrality, r will be the risk-free interest rate earned on assets deposited in a financial intermediary.[4] Given w_t the wage rate, the supply

[4] On each unit of assets deposited in a financial intermediary, agents receive $(1+r)/\alpha$ if they survive to the next period and zero otherwise. Therefore, the expected return for the financial intermediary is r.

of labor is determined by $\varphi_t'(h_t) = w_t/(1+r)$. The wage rate is discounted because wages are paid in the next period as specified below. For entrepreneurs $h_t = 0$ and their utility depends only on consumption.

3.2. Investment project

An investment project requires an initial fixed investment κ_t, which is sunk, and generates revenues according to:

$$y_{t+1} = z_t \cdot F(k_t, l_t)^\theta \tag{2}$$

where y_{t+1} is the output generated with the inputs of capital k_t and labor l_t. The output becomes available at time $t+1$.

The variable z_t is the same for all firms and we will refer to this variable as the "aggregate level of technology". The function F is strictly increasing with respect to both arguments and homogeneous of degree 1. The parameter θ is smaller than 1, and therefore, the revenue function displays decreasing returns to scale. Capital depreciates at rate δ.

With probability $1-\phi$ the project becomes unproductive. Therefore, there are two events in which the firm is liquidated: When the entrepreneur dies and when the project becomes unproductive. The survival probability is $\alpha\phi$. The probability ϕ changes stochastically according to a Markov process. This process is structured such that the survival of the firm declines with its age.

3.3. Financial contract and repudiation

To finance a new project the entrepreneur enters into a contractual relationship with an investor. The financial contract is not fully enforceable. At the end of the period, the entrepreneur has the ability to divert the firm resources (capital and labor) to generate a private return according to the function:

$$D(z_t, k_t, w_t) \;=\; \lambda \cdot y_{t+1} \;=\; \lambda \cdot z_t \cdot F(k_t, l_t(z_t, k_t, w_t))^\theta \tag{3}$$

The definition of the default function uses the fact that the optimal input of labor chosen by the firm will be a function of z_t, k_t and w_t. The optimal input of labor is denoted as $l_t(z_t, k_t, w_t)$.

In case of diversion the firm becomes unproductive and capital fully depreciates. The fact that the firm becomes unproductive makes the issue of renegotiation irrelevant (the production capacity is lost). This specification captures the notion that the default value is closely related to the resources used in the firm and controlled by the entrepreneur. The default value can be interpreted as a backyard technology that generates the present value $\lambda \cdot y_{t+1}$. Notice that diversion is still inefficient if λ is moderately greater than 1. This is because to generate a one-time return from diversion, the ability of the firm to generate profits and the capital stock are permanently lost.[5]

[5] Other specifications of the default value are possible. For instance, we could have used $\lambda \cdot k$.

3.4. Aggregate technology level and balanced growth path

The aggregate technology level z_t grows over time at rate g_z. The growth rate can take two values, g_z^L and g_z^H, with $g_z^L < g_z^H$, and that it follows a first order Markov chain. This is similar to the specification of the technology shock made in many business cycle models. As a special characteristic, our specification features regime switches.

Assume that the economy can be in two different regimes denoted by $i \in \{1, 2\}$. The transition probabilities for the growth rate of z in these two regimes are $\Gamma_1(g_z'/g_z)$ and $\Gamma_2(g_z'/g_z)$ respectively. The regime switch is governed by the transition probability matrix $\Upsilon(i'/i)$. The 1990s are assumed to have experienced a regime switch that changed the expected future growth even if the actual growth rate of z did not change. A similar specification has been used in Danthine, Donaldson & Johnsen (1998).

The growth in the aggregate level of technology z_t allows the economy to experience unbounded growth. To insure stationarity around some trend, it is necessary to make particular assumptions about the disutility from working, $\varphi_t(h)$, and the initial set up investment of a new firm, κ_t. Define $1 + g_t = (1 + g_{z,t})^{\frac{1}{1-\theta\epsilon}}$ where the parameter ϵ is the capital share parameter in the function $F(k, l) = k^\epsilon l^{1-\epsilon}$. Moreover, define $A_t = \prod_{j=1}^{t}(1 + g_j)$. We assume that the disutility from working takes the form $\varphi_t(h) = \chi A_t h^\nu$. This particular specification can be justified by interpreting the disutility from working as the loss in home production where the home technology evolves similarly to the market technology. The set up investment of a new firm is assumed to take the form $\kappa_t = A_t\kappa$. Given these specifications of the disutility from working and the set up investment, the economy will fluctuate around the stochastic trend A_t. Therefore, all growing variables will be detrended by A_t.

3.5. Stock market value

To use a more compact notation, define $R(z_t, k_t, w_t) = (1-\delta)k_t + z_t F(k_t, l(k_t, w_t))^\theta - w_t l(k_t, w_t)$ as the firm's resources at the beginning of period $t+1$, after the payment of wages. This notation uses the result that the optimal input of labor is only a function of k_t and w_t. In fact, given the specification of the default value, the first order conditions show that the capital labor ratio is only a function of the wage rate.

If the firm is not liquidated, it will pay the dividend $R(z_{t-1}, k_{t-1}, w_{t-1}) - k_t$, where k_{t-1} was the capital invested in the previous period and k_t is the new capital input. If the firm is liquidated, there is no capital investment and the dividend is $R(z_{t-1}, k_{t-1}, w_{t-1})$. The (non-detrended) market value of the firm, P_t, is the

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While the model would have similar properties, our specification is more convenient because all firms will choose the same capital-labor ratio independently of the production scale. As shown in Section 6., this allows for a unique decomposition of productivity gains between capital deepening and labor reallocation.

discounted value of the firm's dividends, that is,

$$P_t = \left(\frac{1}{1+r}\right) E_t \sum_{j=t}^{\infty} \left(\prod_{s=t}^{j-1} \beta_s\right) \Big[R(z_j, k_j, w_j) - \alpha\phi_j k_{j+1}\Big] \tag{4}$$

where $\beta_s = \alpha\phi_s/(1+r)$. Notice that the capital investment is multiplied by the survival probability $\alpha\phi_j$ because in case of liquidation, the next period capital is zero. Rearranging and dividing by A_t, the value of the firm is:

$$P_t = k_t + E_t \sum_{j=t}^{\infty} \left(\prod_{s=t}^{j-1} \beta_s (1+g_{s+1})\right) \left[-k_j + \left(\frac{1}{1+r}\right) R(k_j, w_j)\right] \tag{5}$$

where now all the variables are detrended.

Although the detrended payments do not display unbounded growth, the detrended value of the firm depends on the expected future growth rates: if the economy is expected to grow faster, future payments will also grow faster. This, in turn, increases the value of the firm today as shown in equation (5).

3.6. Timing summary

Before starting the analysis of the model, the timing is summarize here. All the shocks are realized at the beginning of the period. Therefore, agents' death, firms' death, next period's survival probability, the level of technology (for the new investment), and the growth regime become known at the beginning of the period. Firms enter the period with resources $(1-\delta)\, k_{t-1} + z_{t-1} F(k_{t-1}, l_{t-1})^{\theta}$. These resources are used to pay for the wages of the workers hired in the previous period, $w_{t-1} l_{t-1}$, and to finance the new capital k_t (if the firm is still productive). What is left is paid as dividends. At this stage the firm also decides the new input of labor, l_t, and production takes place. It is at this point that the entrepreneur decides whether to repudiate the contract and divert the resources of the firm. Therefore, the choice to default is made before observing z_{t+1}. This timing convention is convenient for the characterization of the optimal contract. Finally, it is important to re-emphasize the timing of z. The firm knows the level of technology z_t when it chooses the production inputs k_t and l_t. Therefore, there is no uncertainty about the return from current investment. Only the returns from future investments are uncertain.

4. Equilibrium with enforceable contracts

This section characterizes the allocation when contracts are fully enforceable and the entrepreneur is unable to divert the firm's resources. In this case, all firms will employ the same input of capital $\bar{k}$ which is given by:

$$\bar{k} = \arg\max_k \left\{-k + \left(\frac{1}{1+r}\right) R(k, w)\right\}. \tag{6}$$

In this simple economy, the detrended wage is constant because there is a constant number of firms (entrepreneurs) and the disutility from working grows at the same rate as the whole economy.

A regime switch, that is, a change in the transition probability of g, affects the value of a firm (because it affects the probability distribution of future $g's$). However, if the regime switch is not accompanied by a change in the current value of g, it does not affect the real variables of the economy. In contrast, the next section shows that when contracts are not fully enforceable, a regime switch affects the production decisions and the aggregate productivity of labor even if the actual growth rate of z does not change.

5. Equilibrium with limited enforceability

This section contains a characterization of the optimal contract, firm initial conditions and the equilbrium with limited enforceability.

5.1. Optimal contract

A contract specifies the payments to the entrepreneur, c_t, the payment to the investor, τ_t, and the capital investment, k_t, for each history realization of states. The payments to the entrepreneur are constrained to be nonnegative.

Let q_t be the value of the contract for the entrepreneur and S_t the total surplus. All these variables are detrended by $A_t = \prod_{j=1}^{t}(1+g_j)$. Furthermore, denote by $\mathbf{s}$ the aggregate states of the economy and $\hat{\mathbf{s}} = (\mathbf{s}, \phi)$ the aggregate states plus the individual survival probability ϕ. The variables included in $\mathbf{s}$ are the 'exogenous' states for the firm. The contractual problem can be written recursively as follows:

$$S(\hat{\mathbf{s}}, q) = \max_{k, c(\hat{\mathbf{s}}'), q(\hat{\mathbf{s}}')} \left\{ -k + \left(\frac{1}{1+r}\right) R(k, w(\mathbf{s})) + \beta E(1+g') S(\hat{\mathbf{s}}', q(\hat{\mathbf{s}}')) \right\} \quad (7)$$

subject to

$$q = \beta E(1+g')\Big[c(\hat{\mathbf{s}}') + q(\hat{\mathbf{s}}')\Big] \quad (8)$$

$$\beta E(1+g')\Big[c(\hat{\mathbf{s}}') + q(\hat{\mathbf{s}}')\Big] \geq D(k, w(\mathbf{s})) \quad (9)$$

$$c(\hat{\mathbf{s}}') \geq 0, \; q(\hat{\mathbf{s}}') \geq 0 \quad (10)$$

The function $S(\hat{\mathbf{s}}, q)$ is the end-of-period surplus of the contract, net of the cost of capital. If k is invested—which represents a cost—the discounted gross revenue paid in the next period equals $(1/(1+r))R(k, w(\mathbf{s}))$. Notice that the discount factor $\beta = \alpha\phi/(1+r)$ is known in the current period but changes stochastically over time because it depends on ϕ.

Condition (8) is the promise-keeping constraint, (9) is the enforceability constraint (incentive-compatibility) and (10) imposes the non-negativity of the payments to the entrepreneur. The term $(1+g')$ comes from the detrending procedure and the prime denotes next period variables. In the above problem, the optimal policy when the firm is liquidated is taken as given. This policy consists of setting consumption and continuation utility equal to zero. This is optimal given that the entrepreneur will permanently loose the ability to run a firm.

Coherently with the formulation of the surplus function, the aggregate states of the economy are given by the current growth in the aggregate level of technology, g_z, the current regime governing the future growth rates of technology, i, and the distribution (measure) of firms over ϕ and q. The recursive problem can be solved once the wage rate $w(\mathbf{s})$ and the distribution function (law of motion) for the aggregate states, denoted by $\mathbf{s}' \sim H(\mathbf{s})$, are known.

Denote by μ and γ the Lagrange multipliers associated with the promise-keeping constraint (8) and the enforceability constraint (9). Conditional on the survival of the firm, the first order conditions are:

$$\left(\frac{1}{1+r}\right) R_k(k, w(\mathbf{s})) - 1 - \gamma D_k(k, w(\mathbf{s})) \; = \; 0 \tag{11}$$

$$\mu(\hat{\mathbf{s}}') + \gamma - \mu \; = \; 0 \qquad\qquad \text{for all } \hat{\mathbf{s}}' \tag{12}$$

$$\mu - \gamma \geq \; 0, \qquad\qquad (= \text{if } c(\hat{\mathbf{s}}') > 0) \tag{13}$$

$$\beta E(1+g')\Big[c(\hat{\mathbf{s}}') + q(\hat{\mathbf{s}}')\Big] - q = 0 \tag{14}$$

$$q - D(k, w(\mathbf{s})) \geq 0 \qquad\qquad (= \text{if } \gamma > 0) \tag{15}$$

Condition (13), combined with condition (12), implies that the payment to the entrepreneur $c(\hat{\mathbf{s}}')$ is zero if $\mu(\hat{\mathbf{s}}')$ is greater than zero. This has a simple intuition. Because μ decreases when the enforceability constraint is binding (see condition (12)), when $\mu(\hat{\mathbf{s}}')$ reaches the value of zero, this constraint will not be binding in future periods, that is, $\gamma = 0$ for all possible realizations of $\hat{\mathbf{s}}'$. In this case the firm always employ the optimal input of capital $\bar{k}(\mathbf{s})$ as shown in (11). Therefore, when $\mu(\hat{\mathbf{s}}') = 0$, the firm is unconstrained. Before reaching the unconstrained status, however, the enforceability constraint (9) can be binding in future periods and γ is greater than zero in some contingencies. This implies that the firm will employ a sub-optimal input of capital and labor. Moreover, in those periods in which the enforceability constraint is binding, condition (15) is satisfied with equality (and zero payments to the entrepreneur, unless the unconstrained status is reached that period). Therefore, this condition determines the growth pattern of the firm. These properties are summarized in the following proposition.

Proposition 1 *There exists $\overline{q}(\hat{\mathbf{s}})$ such that,*

- *(a) The function $S(\hat{\mathbf{s}}, q)$ is increasing and concave in $q \leq \overline{q}(\hat{\mathbf{s}})$.*
- *(b) Capital input is the minimum between $k = D^{-1}(q, w(\mathbf{s}))$ and $\bar{k}(\mathbf{s})$.*

- *(c) If* $q \leq \beta E(1+g')\overline{q}(\hat{\mathbf{s}}')$*, the entrepreneur's payment* $c(\hat{\mathbf{s}}')$ *is zero.*
- *(d) If* $q > \beta E(1+g')\overline{q}(\hat{\mathbf{s}}')$*, there are multiple solutions to* $c(\hat{\mathbf{s}}')$*.*

Proof. Using the change of variable $x = k^\theta$, it can be shown that problem (7) is a standard concave problem. The uniqueness of the function $S(\hat{\mathbf{s}}, q)$ can be proved by showing that the optimization problem is a contraction. The concavity derives from the fact that the recursion preserves concavity. The other properties derive directly from the first order conditions (11)-(15). ■

Therefore, the dynamics of the firm have a simply structure. The promised value and the input of capital grow on average until the entrepreneur's value reaches $\overline{q}(\hat{\mathbf{s}})$. At this point the input of capital is kept at the optimal level $\bar{k}(\mathbf{s})$ and the value of the firm, after capital investment, is $P(\hat{\mathbf{s}}) = \bar{k}(\mathbf{s}) + S(\hat{\mathbf{s}}, \overline{q}(\hat{\mathbf{s}}))$.

5.2. Initial conditions

Assuming competition in financial markets, the initial contract solves:

$$\begin{aligned} q^0(\hat{\mathbf{s}}) \;&=\; \max \;\; q \\ \text{s.t.} \;\; S(\hat{\mathbf{s}}, q) - q \;&\geq\; \kappa \end{aligned} \tag{16}$$

This problem maximizes the value of the contract for the entrepreneur, q, subject to the participation constraint for the investor. The solution is unique and satisfies the zero-profit condition $S(\hat{\mathbf{s}}, q) - q = \kappa$. This is because the function $S(\hat{\mathbf{s}}, q)$ is increasing and concave, and for $q \geq \overline{q}(\hat{\mathbf{s}})$ its slope is zero. Therefore, above some q, the function $S(\hat{\mathbf{s}}, q) - q$ is strictly decreasing in q.

The determination of the initial value of q is shown in Figure 2. This figure plots the value of the contract for the investor, $S(\hat{\mathbf{s}}, q) - q$, as a function of q. The initial value of q—and therefore, the initial input of capital—is given by the point in which the curve crosses the set up investment κ.

[Place Figure 2 here]

Figure 2 shows how the initial conditions of the contract are affected by an increase in the value of new firms. This is captured by an upward shift in the value of the contract for the investor, that is, the function $S(\hat{\mathbf{s}}, q) - q$. The new investor's value intersects κ at a higher level of q. Because higher values of q are associated with higher values of k (remember that for constrained firms $q = D(k, w(\mathbf{s}))$), this will increase the initial investment of new firms, and therefore, the aggregate stock of capital and employment. In the quantitative exercise of Section 6., the increase in the value of a firm is generated by a regime switch that increases the likelihood of higher future growth.

5.3. General equilibrium

We provide here the definition of a recursive equilibrium. The aggregate states are given by the current growth rate g_z, the current growth regime, i, and the distribution (measure) M of firms over ϕ and q. Therefore, $\mathbf{s} = (g_z, i, M)$. The aggregate states plus the individual survival probability have been denoted by $\hat{\mathbf{s}} = (\mathbf{s}, \phi)$.

Definition 2 (Recursive equilibrium) *A recursive competitive equilibrium is a set of functions for (i) consumption $c(\hat{\mathbf{s}})$ and working hours $h(\hat{\mathbf{s}})$ for workers; (ii) contract surplus $S(\hat{\mathbf{s}}, q)$, investment $k(\hat{\mathbf{s}}, q)$, consumption $c(\hat{\mathbf{s}}, q)(\hat{\mathbf{s}}')$ and wealth evolution $q(\hat{\mathbf{s}}, q)(\hat{\mathbf{s}}')$ for entrepreneurs; (iii) initial condition for new firms $q^0(\hat{\mathbf{s}})$; (iv) wage $w(\mathbf{s})$; (v) aggregate demand and supply of labor; (vi) aggregate investment from firms and aggregate savings from workers and entrepreneurs; (vii) distribution function (law of motion) $\mathbf{s}' \sim H(\mathbf{s})$. Such that: (i) workers' decisions are optimal; (ii) entrepreneurs' investment, consumption and wealth evolution satisfy the optimality conditions for the financial contract (conditions (11)-(15)), and the surplus satisfies the Bellman's equation (7); (iii) the wage clears the labor market; (iv) the capital market clears (investment equals savings); (v) the law of motion $H(\mathbf{s})$ is consistent with the individual decisions and the stochastic process for g_z and ϕ.*

6. Quantitative analysis

This section contains the calibration the model and demonstrates how a regime switch that leads to higher expected future growth rates—the New Economy—impacts on the macro performance of the economy.

6.1. Calibration

The transition probability matrix for the regime switch is specified as:

$$\Upsilon(i'/i) \; = \; \begin{bmatrix} \rho & 1-\rho \\ 1-\rho & \rho \end{bmatrix}$$

while the conditional transition probability matrices for g_z are:

$$\Gamma_1(g_z'/g_z) \; = \; \begin{bmatrix} 1 & 0 \\ p & 1-p \end{bmatrix}, \qquad \Gamma_2(g_z'/g_z) \; = \; \begin{bmatrix} 1-p & p \\ 0 & 1 \end{bmatrix}$$

If $\rho > 0.5$, the expected future growth rates are higher under the second regime independently of the current growth rate. In the quantitative exercise $\rho \approx 1$, and several values for p are considered.

Denote by $x = (g_z, i)$ the couple with the growth rate of z and the current regime i. The state x can take four values. We interpret the state $(g_z^L, 1)$ as the state prevailing during the period 1972:2-1995:4 and the state $(g_z^L, 2)$ as the one prevailing during the period 1995:4-2000:4. Finally, the state $(g_z^H, 2)$ is interpreted as the new economy.

Consistent with this interpretation, g_z^L is calibrated to the growth rate in trend productivity during the period 1972:2-1995:5. As reported in Table 1, the growth in productivity during this period was 1.4% per year. Therefore, we set $g^L =$

$(g_z^L)^{1/(1-\theta\epsilon)} = 0.014$. The value of g_z^H is the growth rate in the "New Economy". According to the citation in Ip and Schlesinger (2001), the New Economy was believed to grow at rates exceeding the previous rates by as much as 1.5 percent. Accordingly, $g^H = (g_z^H)^{1/(1-\theta\epsilon)} = 0.029$.

Formally, our computational exercise consists of simulating the artificial economy for the following sequence of realized states:

$$x_t = \begin{cases} (g_z^L, 1), & \text{for } t = -\infty : 0 \\ (g_z^L, 2), & \text{for } t = 1 : N \end{cases}$$

In words, the assumption is that the economy has been in the state $x = (g_z^L, 1)$ for a long period of time. This period has been sufficiently long for the economy to converge to the long-term equilibrium associated with this state. Starting from this initial equilibrium, there is a regime switch and the new state becomes $x = (g^L, 2)$. We will then consider a sequence of realizations of this state and compute the continuation equilibrium for the following N periods. Therefore, after the regime switch, the level of technology continues to grow at rate g_z^L even though in each period there is a positive probability of transiting to g^H (New Economy). Although these are very extreme assumptions, they capture the main idea that in the 1990s the likelihood of a New Economy increased.

We now describe the calibration of the other parameters. The period in the model is one year. The intertemporal discount rate (equal to the interest rate) is set to $r = 0.02$ and the survival probability to $\alpha = 0.99$. Notice that firms' profits are discounted more heavily than r because firms survive with probability $\alpha\phi$.

The detrended disutility from working takes the form $\varphi(l) = \chi \cdot l^\nu$ and the supply of labor is determined by the first order condition $\nu\chi l^{\nu-1} = w/(1+r)$. Therefore, the elasticity of labor is $1/(\nu - 1)$. Blundell and MaCurdy(1999) provide a survey of studies with estimates of this elasticity. For men, the estimates range between 0 and 0.2, while for married women they range between 0 and 1. Based on these numbers, $\nu = 3$ which implies an elasticity of 0.5. After fixing ν, the parameter χ is chosen so that one third of available time is spent working.

The fraction of agents with entrepreneurial skills, e, determines the ratio of workers to firms. This is irrelevant for for the quantities of interest. It only affects the wage level.

The production function is specified as $(k^\epsilon l^{1-\epsilon})^\theta$. Atkeson, Khan & Ohanian (1996) provide some discussion justifying a value of $\theta = 0.85$. The parameter ϵ, then, is such that the labor income share is close to 0.6. For unconstrained firms the labor income share is equal to $\theta(1-\epsilon)$. Because most of the production comes from unconstrained firms, this condition is used to calibrate ϵ. Using the first order condition for the optimal input of capital (which is satisfied for unconstrained firms), the depreciation rate can be expressed as $\delta = \theta\epsilon/(K/Y) - r$. With a capital-output ratio of 2.5 and the above parameterization of θ, ϵ and r, the depreciation rate is $\delta = 0.08$.[6]

[6] Notice that the economy-wide capital-output ratio will not be exactly 2.5 because there are also constrained firms. However, because the production share of constrained firms is small, these numbers will not be very different from the targets.

The survival probability ϕ takes two values, $\underline{\phi}$ and $\overline{\phi}$, with $\underline{\phi} < \overline{\phi}$. When firms are born, their initial survival probability is $\underline{\phi}$. Over time, these firms may mature with some probability ξ and their survival probability increases to $\overline{\phi}$ forever. This allows us to capture the dependence of the firm survival on age. We set $\underline{\phi} = 0.91$ and $\overline{\phi} = 0.99$. Together with the one percent probability that the entrepreneur dies, these numbers imply that new firms face a 10 percent probability of exit while the exit of mature firms is 2 percent. These numbers are broadly consistent with the U.S. data for the manufacturing and business service sector: as reported by the OECD (2001), only 50% of entrant firms are still alive after 7 years which is consistent with the 10% yearly probability of exit assumed for new firms. After parameterizing $\underline{\phi}$ and $\overline{\phi}$, the probability that a firm becomes mature is set such that the average exit rate is 6 percent. This is in the range of values resulting from several empirical studies about firms' turnover as in Evans (1987) and OECD (2001).

Two other parameters need to be calibrated: the default parameter λ and the set up investment κ. These parameters are important for determining the initial size of new firms: higher values of these parameters imply smaller sizes of new firms. Our calibration target is to have an initial size which is 25% of the average size of incumbent firms. This is somewhat larger than the value of 15% reported by OECD (2001) for the U.S. business sector. This discrepancy is allowed because our model does not incorporate other factors, such as learning, that affect the initial size of firms. The parameter λ is especially important to determine the feasible size heterogeneity between constrained and unconstrained firms. In particular, for small values of λ, the initial size of firms can not be very small. A value of $\lambda = 3$ allows us to reach our calibration target for the initial size of new firms. After setting $\lambda = 3$, the value of κ is determined such that k_0 is 25% the capital of incumbent firms.[7]

6.2. Computation of equilibrium

Equations (11)-(15) with the initial condition $q + \kappa = S(\hat{\mathbf{s}}, q)$ provide the basic conditions that need to be satisfied by the optimal contract. If the terms $E(1 + g')q(\hat{\mathbf{s}}')$ and $E(1+g')S(\hat{\mathbf{s}}', q(\hat{\mathbf{s}}'))$ were known, these conditions would be sufficient to solve the model. The numerical procedure, then, is based on the parametrization of these two functions on a grid of values for μ. The chosen parametrization depends on the particular problem that is solved.

In the computation of the transitional equilibrium, we assume $\rho = 0$. Therefore, when there is the regime switch, the economy continues to stay in that regime. Moreover, if the economy switches to the high growth rate, it will continue to grow at this rate forever. The equilibrium computed under these assumptions is an approximation to the case in which ρ is not very different from zero as assumed in the calibration section. A more detailed description of the numerical procedure is

[7] Larger values of λ (and smaller values of κ) would reduce the speed of convergence to the unconstrained status but would not change the main results. However, there are some constraints on how large λ could be. Indeed, for very large λ, the value of defaulting can become larger than the value of the firm.

available upon request from the authors.

6.3. Simulation results

Figures 3 and 4 plot the detrended responses of several variables (in percents) after the economy switches to the second regime but z continues to grow at g_z^L. Several values of p are considered.

The impulse responses show how the expectations about the New Economy leads to an improvement in the productivity of labor. First, the higher value of p increases the value of firms and generates a stock market boom (panel *a*). After the stock market boom, new firms get higher initial financing and hire more labor (panel *b*). With the exception of the first period, this implies that the demand of labor increases and pushes up the wage rate (panel *c*).[8] A higher wage rate induces unconstrained firms to reduce employment (panel *d*). Also, the higher wage rate increases the intensity of capital (panel *e*). As a result of these events, the productivity of labor increases as shown in panel *f*.

The productivity improvement derives in part from the reallocation of labor to younger firms (reallocation effect) and in part from the increase in capital intensity (capital deepening effect). Given that all firms run the same production technology $z(k^\epsilon l^{1-\epsilon})^\theta$ and choose the same capital-labor ratio, the aggregate productivity of labor can be written as $z\left(\frac{K}{L}\right)^{\theta\epsilon}\sum_i \omega_i l_i^{\theta-1}$, where l_i is the labor employed by each firm of type i and ω_i is the share of aggregate labor employed by all firms of type i. Taking logs and first differences

$$\Delta\log(\text{LabProd}) = \Delta\log z + \theta\epsilon\Delta\log\left(\frac{K}{L}\right) + \Delta\log\left(\sum_i \omega_i l_i^{\theta-1}\right). \tag{17}$$

The first element on the right-hand-size is constant because the growth rate of z does not change in our simulation. The second element is the contribution of capital deepening while the third is the contribution of labor reallocation.[9]

When $p = 0.2$, labor productivity increases by about 2.3% during the five years following the regime switch. Of this increase, about half is generated by capital deepening and the other half by the reallocation effect (plot *g* and *h*). As seen in Section 2., this corresponds roughly to about half of the actual productivity acceleration experienced by the U.S. economy during the second half of 1990s.[10]

[8] In the first period the demand of labor decreases because old firms that are still financially constrained reduce their investment. This is a feature of the optimal contract. The negative investment of existing constrained firms will be overturned later by the entrance of new firms.

[9] It is common in growth accounting to use a constant return-to-scale production function to determine multifactor productivity as the residual contribution to output growth not accounted for by the different factors of production. The application of this procedure to data generated by our model requires the imposition of $\theta = 1$ and would mistakenly attribute the reallocation effect (the last term in equation (17)) to multifactor productivity.

[10] Sensitivity with respect to changes in the degree of decreasing returns is quite moderate. For instance, with $\theta = 0.95$ the productivity increase is still roughly one third of our benchmark case. Results are also somewhat sensitive to the labor supply elasticity, governed by ν. With less elastic labor the productivity effect is stronger.

For the large stock market boom (Figure 3 panel a), the calibration of the interest rate r and the survival probability ϕ are key. To see this, consider the steady state value of a firm once it has become unconstrained:

$$P = \frac{d}{1 - \left(\frac{\alpha\phi}{1+r}\right)(1+g)} \tag{18}$$

Here d denotes the detrended values of dividends which is constant in the steady state. The term $\alpha\phi/(1+r)$ is the discount factor. This factor is multiplied by $1+g$ because dividends are detrended. This formula makes clear that the value of the firm is more responsive to changes in g when the term $\left(\frac{\alpha\phi}{1+r}\right)(1+g)$ is closer to 1. Therefore, the value of the firm becomes more responsive to g when r is small and ϕ is large. In our calibration the value of ϕ is relatively small for new firms but relatively high for mature firms. The high sensitivity of the market value derives from the fact that most of this value is generated by mature firms.

Figure 4 shows the impact of the regime switch on other macroeconomic variables. With the exception of the first period, employment and production increase persistently. Panel c shows that the wage or labor share of output also increases after the regime switch as a consequence of the higher wages. The last panel plots the fraction of firms that are not financially constrained. This fraction increases after the regime switch. This is another way to see how the stock market boom relaxes the tightness of financial constraints.

7. Discussion

This section further discusses two key features of our analysis, namely the role of financial constraints and the role of risk neutrality.

7.1. The role of financial constraints

As shown in Section 4., financial constraints have the role of linking expectations about future productivity to production decisions and the firm size distribution. Other modelling features could plausibly generate such a link. However, the link established by the financial frictions in our model is particularly successful in generating a positive relationship between aggregate labor productivity and expected future productivity. Indeed, in our model, positive beliefs about future productivity have a big positive effect on the size of newly entering firms as their financial constraint are relaxed. Instead, the production decision of unconstrained firms is only affected through the general equilibrium effects of the wage rate change. This combination can produce a concentration of the firm size distribution with only a moderate increase in the aggregate input of labor. The following example illustrates this mechanism in more detail.

Assume that there are only two types of firms: small constrained firms and large unconstrained firms. A small firm employs l_1 units of labor and a large firm employs l_2 units of labor. With n the fraction of small firms, the average (per-firm) employment is equal to $l = n \cdot l_1 + (1-n) \cdot l_2$. The reallocation term derived in equation (17) can be written as:

$$\Delta\log\left(\sum_{i=1,2}\omega_i l_i^{\theta-1}\right) = (\theta-1)\Delta\log(l) + \Delta\log\left[n\left(\frac{l_1}{l}\right)^{\theta} + (1-n)\left(\frac{l_2}{l}\right)^{\theta}\right] \quad (19)$$

The first term on the right-hand-side is a "level effect": given decreasing returns to scale, larger average scale reduces productivity. The second term on the right-hand-side is the "relative reallocation effect": the smaller the difference in size between small and large firms, the greater is the productivity of labor. As shown in the previous section, a stock market boom induces both a level effect (increase in the average size of firms l) and a relative reallocation effect (increase in l_1/l and decrease in l_2/l).

In the baseline model, the aggregate employment has increased by about 2% after 5 years. Therefore, with $\theta = 0.85$, the level effect (first term in 19) reduces productivity by about 0.30%. Table 3 shows the increase in productivity due to the relative reallocation effect (second term in (19), from eliminating all financial frictions. We consider several initial values of n and l_1/l_2 and the elimination of all the financial frictions implies $l_1/l = l_2/l = 1$. This is the maximal effect that can be obtained through the relative reallocation mechanism.

[Place Table 3 here]

As can be seen from the table, for the particular range of initial conditions, the potential gains in productivity due to the relative reallocation mechanism are much larger than the losses in productivity induced by the level effect.

7.2. The role of risk neutrality

Due to our risk neutrality assumption, our analysis abstracts from consumption smoothing considerations. An important question, then, is whether concave utility could overturn our results. There are two factors to consider. On the one hand, the wealth effect on leisure will reduce the supply of labor. This would make the reallocation effect larger because of a higher wage increase. On the other hand, the incentive to increase consumption will raise the interest rate and will reduce the impact of the higher expected growth on asset prices. Firm values could even drop. This would not happen if the intertemporal elasticity of substitution is greater than 1, which can be compatible with high risk aversion, for instance in the case of Epstain-Zin preferences. See Bansal and Yaron (2004) for an application of these preferences to the study of asset prices.

8. Conclusion

This article develops a general equilibrium model with financial frictions in which a stock market boom can generate an economic expansion. A key feature of our model is that this boom generates an increase in productivity driven by changes in the firm size distribution. The reaction of the economy to a stock market boom is consistent with a number of features of the 1990s expansion in the U.S. economy.

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Table 1: Decomposition of Growth in Output Per Hour, 1995-2000.

Average annual growth 1995-2000	**2.55**
Average annual growth 1973-1995	**1.40**
Acceleration of growth = 1.15%	
Contribution of labor quality	-0.01
Contribution of MFP in computer-sector	0.31
Contribution of capital deepening	0.43
Contribution of MFP outside computer-sector	0.42

Source: Baily (2002)

Table 2: Average market value of new listed firms relative to incumbents.

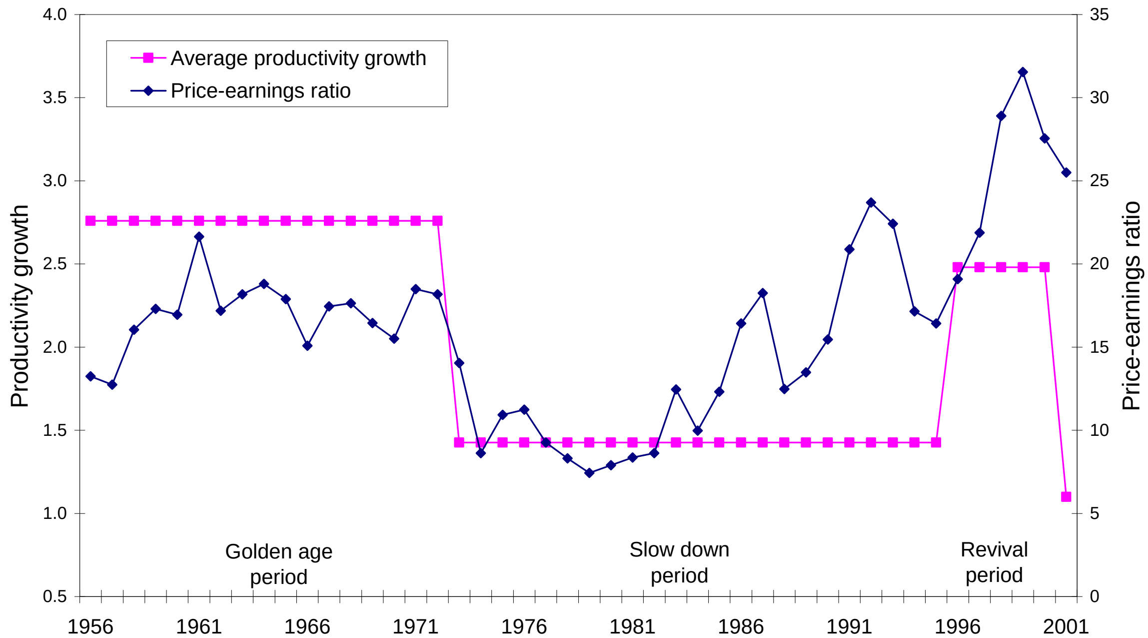
	Number of new listings	Ave percentile NYSE	Ave percentile Local Exchanges
1973-1979	149	9.3	45.2
1980-1989	573	8.2	48.3
1990-2000	622	17.5	55.5

Source: *Fama and French (2002)*

Table 3: Relative reallocation effect from eliminating all the financial constraints. The value of θ is 0.85.

	$n = 0.3$	$n = 0.4$	$n = 0.5$	$n = 0.6$
$\frac{l_1}{l_2} = 0.1$	3.04	4.15	5.29	6.41
$\frac{l_1}{l_2} = 0.2$	1.98	2.62	3.21	3.70
$\frac{l_1}{l_2} = 0.3$	1.31	1.68	2.00	2.21

Figure 1: Productivity growth and price-earning ratio.



Source: Bureau of Labor Statistics and Economic Report of the President

Figure 2: Initial conditions of the optimal contract.

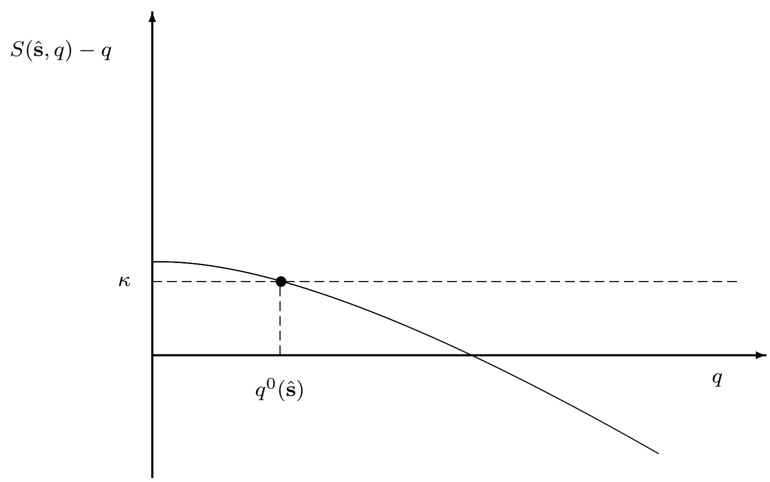


Figure 3: Impulse responses after the regime switch.

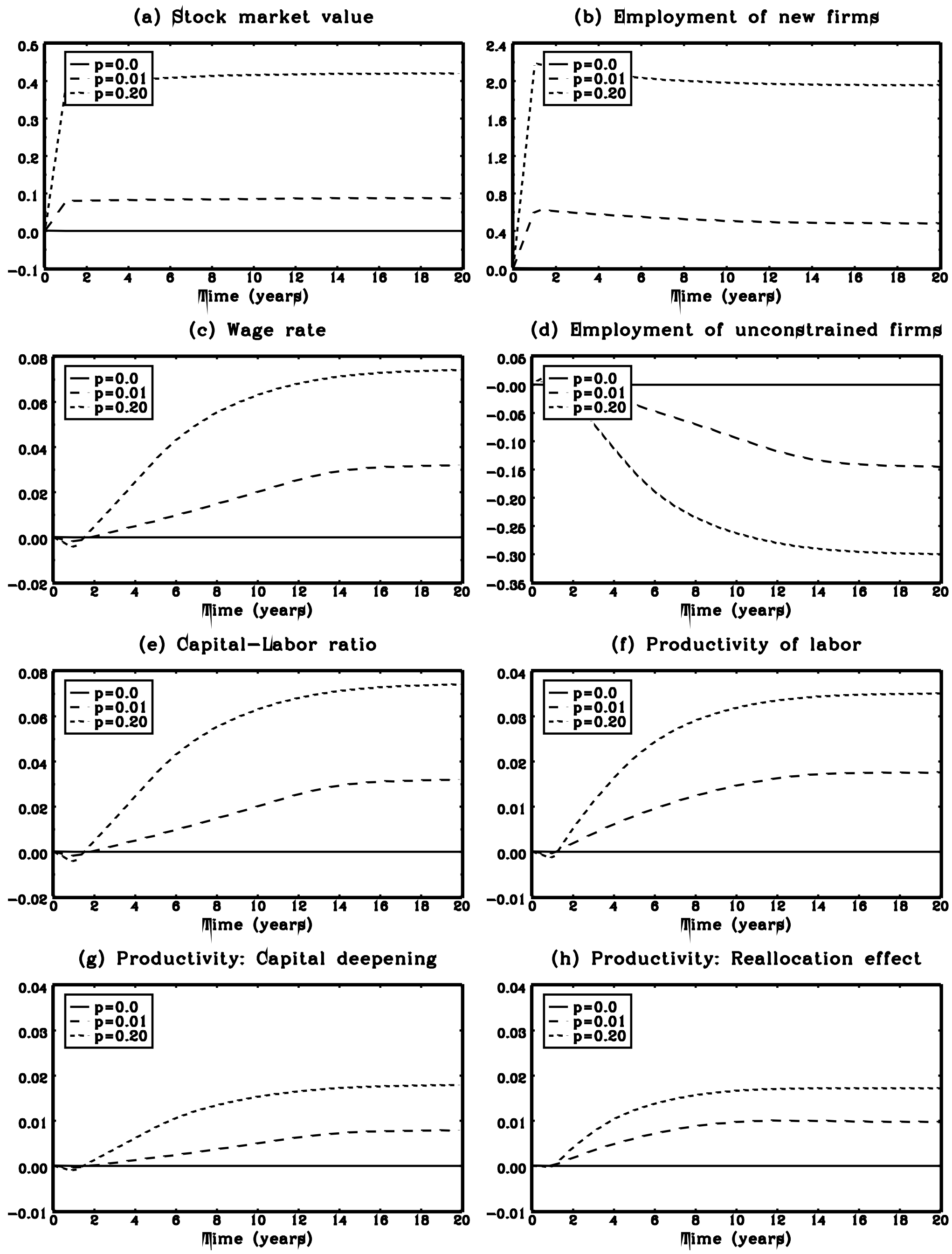


Figure 4: Impulse responses after the regime switch.