Stock market boom and the productivity gains of the 1990s

Urban Jermann
University of Pennsylvania

Vincenzo Quadrini
New York University

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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. In this paper, we propose 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.

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".

In this paper, we propose an interpretation of these events in which the prospect of a New Economy plays a key role in generating the other events. More specifically, we show that the mere prospect of high future productivity growth can generate sizable gains in current productivity, as well as an economic expansion, a stock market boom and a financing boom for new firms. 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 for firms. Diminishing returns make aggregate productivity dependent on the size distribution of firms. In particular, a more concentrated firm-size distribution results in higher aggregate labor productivity.

In our model, an initial improvement in the prospects for having higher 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 wage rates 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. We find that a reasonably calibrated model can generate a cumulative productivity gain of about 2.5%. This productivity gain is driven solely by the prospects of higher productivity growth and would arise even if the increase in technological growth would never occur.

The theoretical framework consists of a general equilibrium model in which investment projects are carried out by individual entrepreneurs and financed through an optimal contract with investors. The structure of the optimal contract is complicated by limited enforceability: the entrepreneur controls the resources of the firm and can use these resources for his own private benefit. 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 firm growth dynamics. See Albuquerque &

Hopenhayn (1997), Cooley, Marimon, & Quadrini (2000) and Monge (2001) and Quintin (2000).

To keep our 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. Also, it should 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, we see our explanation as complementary to the actual improvement in firm level technology which, for simplicity, we omit from the analysis.

Section 1 reviews the main events experienced by the U.S. economy in the 1990s. Section 2 contains an overview of how these facts are linked in our theoretical model and provides the intuition for the main results of the paper. Section 3 presents the detailed analysis of the model and the quantitative results of the calibration exercise. Section 4 provides some empirical evidence in support of the reallocation mechanism described in the paper and 5 concludes.

1 Facts about the 1990s

In this section we provide some quantitative evidence about the above-mentioned five characteristics of the US economy during the second half of the 1990s.

Macroeconomic expansion: The second half of the 1990s features the continuation of one of the longest economic expansions in recent US history with an acceleration in the growth rates of output, employment, investment and wages. Figure 1 presents the growth rates of these four aggregates for the period 1990-2000.

Productivity growth: A recent paper by Gordon (2001) identifies several sources for labor productivity gains during the second half of the 1990s. The sources of productivity gains are reported in Table 1.

Output per hour in nonfarm private business sector has grown at an annual rate of 2.86% during the period 1995:4–00:4 compared to a 1.42% trend in productivity growth during the period 1972:2–95:4. Therefore, there has

Table 1: Decomposition of Growth in Output Per Hour, 1995:4-2000:4.

Actual growth 1995:4-2000:4		**2.86**
Growth trend 1972:2-1995:4		**1.42**
Acceleration of growth = 1.44%		
Contribution of price measurement and labor quality		0.15
Contribution of MFP in computer-sector		0.30
Contribution of capital deepening		0.37
Contribution of MFP outside computer-sector		0.62
- Cyclical component	0.40	
- Structural component	0.22	

Source: Gordon (2001), Oliner & Sichel (2000)

been an acceleration of 1.44%. Abstracting from price measurement and labor quality which count for a small percentage (0.15%), the table decomposes this acceleration in three components. The first component is the growth in multifactor productivity (MFP) in the computers sector. The estimate for this is 0.30%. Capital deepening, which results from the investment boom especially in computers equipment, counts for 0.37%. The remaining 0.62% is the structural acceleration in multifactor productivity outside the computer-producing sector. Gordon further decomposes this last component in cyclical and structural. The cyclical component, which counts for 0.4%, is the part that is estimated to be temporary. This leaves only a 0.22% acceleration which is permanent. Given that the decomposition of the productivity gains between cyclical and structural (trend) is to some extend arbitrary, in our analysis we do not distinguish between these two components. Therefore, according to the above table there is about 0.6% of the productivity acceleration that cannot be explained with the productivity improvements in the computers sector or with capital deepening. Some other factors must have played an important role.[1]

[1] Several studies (see for example Brynjolfsson & Hitt (2000), Jorgenson & Stiroh (2000), Oliner & Sichel (2000)), interpret the 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. In this paper we provide a different interpretation of the driving forces underlying the improvement in

Stock market boom: Equity prices have registered a spectacular increase during the second half of the 1990. During that period the S&P500 or the Dow Jones Industrial indexes have more than doubled. The goal of this paper is to relate this stock market boom to the growth in labor productivity experienced by the U.S. economy during this period. Figure 2 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 labeling of these three sub-periods are taken from Gordon (2001). Because the subdivision in the three periods is to some extent arbitrary, Figures 3a and 3b plot the original series and the trend components computed using a low pass filter containing cycles of 8 years and longer. Clearly, there is a strong positive association between productivity growth and price-earnings ratios. Although the causal relationship can go in both directions, in this paper we will emphasize the channel going from the asset prices to the productivity of labor.

Financing boom for new firms: Figure 4 illustrates the financing boom for new firms with the evolution of the Nasdaq composite index and the amount of venture capital investment. While the association between the value of firms quoted in Nasdaq and venture capital investment is not surprising, it is worth to be emphasized because it shows the close connection between the value that the market attributes to investment projects and the volume of funds injected in those projects. At the beginning of 2000, the size of the venture capital market has reached dimensions of macroeconomic significance. Although these funds were less than 1 percent of GDP, in terms of net private domestic investment they are about 10-15 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. Even if the percentage of firms that go public is small (about 10 percent), the funds raised through IPOs are considerable.

"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

multifactor productivity and capital deepening.

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 & Schlesinger (2001). The same article also describes how this view spread across the Federal Open Market Committee. For instance, referring to a speech of Fed member Mr. Meyer, the article reports:

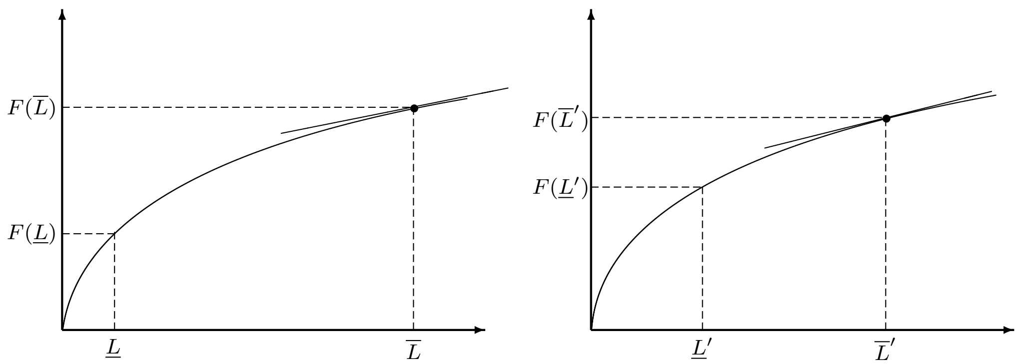
> "'*we can confidently say ... that, since 1995, actual productivity growth has increased.' At the time he suggested that he believed the economy could annually grow by overall as much as 3% without inciting inflation, up from his longtime prior estimate of a 2.5% limit. Soon, thereafter, he indicated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

The goal of this paper is to link these facts within a unified framework and to provide an explanation for the labor productivity improvement which does not rely on network and spill over effects following the diffusion of information and communication technologies.

2 Overview of the main results

In this section we describe informally the model's main mechanisms that link the events documented above. A detailed analysis of the model will be conducted in the next section.

Suppose that there is a fixed number of workers with a constant supply of labor and a fixed number of firms. All firms run the same decreasing return-to-scale technology $F(L)$ with the input of labor L as plotted in Figure 5. Given the concavity of the production function, there is an optimal input of labor which is determined by the equilibrium wage rate. In the absence of financial constraints, all firms will employ the same input of labor $\overline{L}$. However, if the employment of labor requires capital, the presence of financial constraints may limit the ability of the firm to employ $\overline{L}$. Assume there is a fraction of firms that are financially constrained and operate at a sub-optimal scale, and the remaining fraction includes firms that are not constrained and operate at the optimal scale. For simplicity let's assume that half of the firms are financially constrained and employ $\underline{L}$, and the other half are unconstrained and employ $\overline{L}$. This is shown in panel a of Figure 5



a) Before the price boom b) After the price boom

Figure 5: Reallocation of workers and productivity effect.

Because the production function is concave, this allocation of labor is clearly inefficient. Suppose that we are able to reallocate some of the workers from unconstrained firms to the constrained firms as shown in panel b of Figure 5. By reallocating workers from unconstrained firms to constrained firms, aggregate production increases. Because the total number of workers does not change, the productivity of labor also increases.

The main point of the paper is to show that a stock market boom can generate a reallocation of workers similar to the one described above. The idea is that, when the value of a new firm increases, the firm is able to get a higher initial financing from investors. This, in turn, increases the average employment of constrained firms, which in the above graph is captured by the shift to the right of $\underline{L}$. The increase in the demand of labor coming from constrained firms increases the wage rate which in turn reduces the optimal (unconstrained) input of labor $\overline{L}$. This is captured in the graph by the shift to the left of $\overline{L}$. As a consequence of the increase in the size of constrained firms and the decrease in the size of unconstrained firms, the aggregate productivity of labor increases. Therefore, an asset price boom can generate an economic expansion through a productivity improvement.[2]

[2]If we were to compute the Solow residuals using a constant return to scale $z \cdot L$ applied to aggregate data, the improvement in labor productivity would be interpreted as an exogenous increase in z, rather than generated endogenously by the reallocation of resources. In fact, when labor is the only input of production and the technology is constant return-to-scale, z is the productivity of labor. As we will see later in the paper,

In the above example we have made two special assumptions. The first assumption is that labor is perfectly complementary to capital. The relaxation of this assumption may increase the impact of an asset price boom on the productivity of labor. This is because higher wages may induce firms to use more capital per unit of labor (capital deepening). The second assumption was the constancy of the aggregate supply of labor. Although in the full specification of the model we maintain the assumption that the number of workers is fixed, working time depends on the wage rate. The relaxation of this second assumption will weaken the impact of an asset price boom on the productivity of labor. To see this, consider the extreme case in which labor is perfectly elastic. In this case the wage is not affected by the asset price increase and $\overline{L}$ does not change. However, the size of constrained firm $\underline{L}$ will still move to the right. This would imply that the productivity of constrained firms declines while the productivity of unconstrained firms remain unchanged. This may induce a fall, rather than an increase, in the aggregate productivity of labor.[3]

Based on the above considerations, we can summarize the main factors that affect the productivity improvement:

- **Returns to scale**: If the degree of concavity in the production function is high, the reallocation of labor will have large effects on productivity. In the extreme case in which $F(L)$ is linear, the reallocation of labor has no effect on productivity beyond capital deepening.

- **Size heterogeneity**: If the size of constrained firms is small relative to unconstrained firms, the productivity differential between these two groups of firms is large. This implies that the reallocation of labor generates a large productivity gain.

- **Elasticity of labor**: If the elasticity of labor is small, the expansion of constrained firms generates a large increase in the wage rate which in turn induces a large fall in the employment of unconstrained firms. Therefore, the productivity improvement will be higher.

this interpretation also applies in the case in which capital is also an input of production.

[3] In this case the aggregate productivity of labor does not necessarily decrease. In fact, even though the productivity of constrained firms decreases, their employment share increases. Consequently, the impact on aggregate productivity depends on whether the decrease in the individual productivity of constrained firms dominates their increase in the employment share.

In Section 4 we provide some empirical evidence in support of this reallocation mechanism. Before discussing this empirical evidence, however, we turn now to the illustration of this mechanism in our fully specified general equilibrium model.

3 The model

In this section, we start by presenting the elements of the model. We then characterize equilibrium outcomes with fully enforceable contracts and with limited enforcement. We end the section with a discussion of the consequences of an increase in the value of new firms.

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:

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

where r is the intertemporal discount rate, c_t is consumption, l_t are working hours, $\varphi_t(l_t)$ is the disutility from working. We assume that the disutility from working is time dependent as explained below.

Utility flows are discounted by $\alpha/(1+r)$ as agents survive to the next period only with probability α. Given the assumption of risk neutrality, r will be the risk-free interest rate earned on assets deposited in a financial intermediary.[4] The function φ_t is strictly convex and satisfies $\varphi_t(0) = 0$. Denoting by w_t the wage rate, the supply of labor is determined by the condition $\varphi_t'(l_t) = w_t\alpha/(1+r)$. The wage rate is discounted because wages are paid in the next period as specified below. For entrepreneurs $l_t = 0$ and their utility depends only on consumption.

[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. The financial intermediary acts as a life-insurance company and the expected return on these deposits is r.

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

$$y_t = z_t \cdot F(k_t, l_t)^\theta \tag{2}$$

where y_t is the revenue generated at time t given the inputs of capital k_t and labor l_t. The variable z_t is the same for all firms and we will refer to this variable as the "aggregate technology level". The function F is strictly increasing with respect to each of the two 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. In this case the capital fully depreciates and the entrepreneur becomes a worker. Therefore, there are two circumstances in which the firm is liquidated: When the entrepreneur dies and when the project becomes unproductive. The survival probability of the firm is $\alpha\phi$.

The total resources available after production, net of wages, are $(1-\delta)k_t + z_t F(k_t, l_t) - w_t l_t$. Using the optimality condition for the input of labor, we can express l_t as a function of z_t, k_t and w_t, that is, $l(z_t, k_t, w_t)$. We can then express the firm's resources as $R(z_t, k_t, w_t) = (1 - \delta)k_t + z_t \cdot F(k_t, l_t) - w_t l(z_t, k_t, w_t)$.

Financial contract and repudiation: To finance a new project the entrepreneur enters into a contractual relationship with one or more investors.[5] The financial contract is not fully enforceable as the entrepreneur can repudiate the contract.[6] At the end of the period the entrepreneur can appropriate some of the firm resources and run away. The default value is assumed to be an increasing function of the firm's output. This assumption can be justified in different ways. For example, by running the firm the entrepreneur acquires management skills that can be used to run other firms and the skills depend

[5]Given the assumption that agents are risk neutral, whether the entrepreneur signs a contract with one or more investors does not change the nature of the contract. Therefore, we will use the term "investor" to refer to a single or a group of agents that enter into a contractual relationship with the entrepreneur.

[6]The paper is related to the existing literature on optimal contracting with limited enforceability. See, for example, Albuquerque & Hopenhayn (1997), Alvarez & Jermann (2000), Cooley et al. (2000), Kehoe & Levine (1993), Marcet & Marimon (1992), Monge (2001), Quintin (2000).

on the size of the firm currently run. An alternative assumption is that the entrepreneur can appropriate the revenues of the firm and use these revenues to set up a new firm. For simplicity we do not model explicitly these alternative situations. We simply assume that the default value is a linear function of the firm's revenues, that is, $D(z_t, k_t, w_t) = \lambda \cdot y_{t+1} = \lambda \cdot z_t \cdot F(k_t, l_t(z_t, k_t, w_t))^\theta$. This particular specification of the default value will be convenient in the technical analysis of the model. Notice that λ is allowed to be greater than 1. In this case the interpretation is that the entrepreneur can use the diverted resources to run an alternative and unspecified technology. This alternative technology generates a flow of revenues or utility in every period. A more interesting assumption would have been to allow the entrepreneur to use the funds to run another project. However, this would have made the problem unnecessarily complicated for the purpose of this paper. All we want, here, is that the value of defaulting is increasing in the resources of the firms.

Aggregate technology level and balanced growth path The aggregate technology level z_t grows over time at rate g_z. We assume that the growth rate can take two values, g_z^L and g_z^H, with $g_z^L < g_z^H$. The economy can switch from one growth regime to the other with some probability p_t. This probability defines the likelihood that the economy switches from the current growth regime to the other. The next period value of p is drawn from the probability distribution $\Gamma(p'|p, g_z')$. For the moment we allow this distribution to depend on the current p and the next period growth regime g_z'. The growth rate g_z and the switching probability p—which we denote by $x \equiv (g_z, p)$—can be interpreted as aggregate shocks. The stochastic distribution of x (joint distribution of g_z and p) is derived from the distribution function $\Gamma(p'|p, g')$.

The growth in the aggregate level of technology z_t allows the economy to experience unbounded growth. To insure stationarity around some trend, we need to make particular assumptions about the disutility from working 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 $\varphi_t = \pi A_t l^\nu$. This particular specification can be justified by interpreting the disutility from working as the loss in home production where the production technology evolves similarly to the market technology. Regarding the set up investment κ_t, we assume that this initial cost grows over time at rate $1+g$ so that the detrended value κ_t/A_t is a constant. Given the particular specification of the function φ_t and the fixed investment κ_t, the economy will fluctuate around the stochastic trend A_t. Therefore, in the analysis of the following sections all the endogenous variables that experience unbounded growth will be detrended by the factor A_t.

Because the detrended value of z_t is a constant, when we refer to the detrended values of the production function, the firm's resources and the repudiation value, we will omit the variable z and use the notation $F(k,w)$, $R(k,w)$ and $D(k,w)$.

Stock market value: Before characterizing the properties of the model, let's define here the market value of a firm. In each period a firm pays total dividends $R(z_{t-1},k_{t-1},w_{t-1}) - \alpha\phi k_t$, where k_{t-1} was the capital decided in the previous period and k_t is the capital invested this period. Investment is conditional on the survival of the firm and therefore it is multiplied by the survival probability $\alpha\phi$.

The (non-detrended) market value of the firm, denoted by P_t, is the discounted value of the firm's payments, starting next period, that is,

$$P_t = \left(\frac{1}{1+r}\right) E_t \sum_{j=t}^{\infty} \beta^{j-t} \Big[R(z_j,k_j,w_j) - \alpha\phi k_{j+1}\Big] \tag{3}$$

where $\beta = \alpha\phi/(1+r)$. The market price can also be written as:

$$P_t = k_t + E_t \sum_{j=t}^{\infty} \beta^{j-t} \left[-k_j + \left(\frac{1}{1+r}\right) R(z_j,k_j,w_j)\right] \tag{4}$$

which will give us a convenient formulation for the later analysis.

The price P_t grows over time because the payments of the firm also grow. The detrended price is obtained by dividing the whole expression by A_t. After some rearrangement, the detrended price is:

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

where now all the variables are detrended.

Timing summary: Before starting the analysis of the model, we summarize here the timing of the model. All the shocks are realized at the beginning of the period. Therefore, agents' death, firms' death, growth rate of z and switching probability become known at the beginning of the period. Firms enter the period with resources $F(k_{t-1}, l_{t-1}) + (1-\delta)\, k_{t-1}$, and pay out profits and labor income associated with last periods production. Given the observation of the aggregate shocks $x \equiv (g_z, p)$, if the firm remains productive it decides capital and labor inputs and production takes place. It is at this point that the entrepreneur decides whether to repudiate the contract. Therefore, the choice to default is made after production but before observing the next period value of q. This timing convention is convenient for the characterization of the optimal contract.

3.1 The economy with enforceable contracts

We first characterize allocations when contracts are fully enforceable. In this case, all firms will employ the same input of capital $\bar{k}$ which is given by:

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

where the detrended wage is constant in this simple economy. The constancy of the detrended values of k and w derives from the fact that in the economy there is a constant number of entrepreneurs (firms) and the disutility from working grows at the same rate in which the whole economy grows.

Using equation (5), the detrended market value of the firm is:

$$P_t = \bar{k} + E_t \sum_{j=t}^{\infty} \left(\prod_{s=t+1}^{j} \beta(1+g_s) \right) \left[-\bar{k} + \left(\frac{1}{1+r}\right) R(\bar{k}, w) \right] \tag{7}$$

Notice that, although the detrended dividends are constant, the detrended value of the firm depends on the expected future growth rates of the economy: if the economy is expected to grow faster, future dividends will also grow at a higher rate. This, in turns, increases the value of the firm today. In the detrended model this is captured by discounting future (detrended) dividends at a lower rate.[7]

[7]The positive impact of future growth rates on current asset prices is not robust to alternative formulations of the utility function. For example, if the utility function is of

When a new firm is created, the value P_t is shared between the investor and the entrepreneur. In the case of competitive financial markets, the investor will get the cost to create the new firm, $\kappa + \bar{k}$, and the entrepreneur will get $P_t - \kappa - \bar{k}$.

In this environment, the probability of a regime switch p_t affects the value of a firm (because it affects the probability distribution of future $g's$), but it is completely neutral with respect to the real variables of the economy. Therefore, a change in likelihood of a regime switch does not have any real effect unless this switch actually takes place. In contrast to this, we will see in the next section that when contracts are not fully enforceable, p affects not only the value of the firm but also production decisions and aggregate productivity.

3.2 The economy with limited enforceability

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 the states. We assume that the payments to the entrepreneur cannot be negative which seems natural given that initially entrepreneurs do not have assets. Also denote by q_t the value of the contract for the entrepreneur and by S_t the total surplus. All these variables are detrended by $A_t = \prod_{j=1}^{t}(1+g_j)$. Given $\mathbf{s}$ the aggregate states of the economy, the contractual problem can be written recursively as follows:

$$S(\mathbf{s}, q) = \max_{k, c(\mathbf{s}'), q(\mathbf{s}')} \left\{ -k + \left(\frac{1}{1+r}\right) R(k, w(\mathbf{s})) + \beta E(1+g')S(\mathbf{s}', q(\mathbf{s}')) \right\} \quad (8)$$

the CES type with the parameter of risk aversion greater than 1, then future growth rates would have a negative impact on asset prices. This is because in this class of utility functions the intertemporal elasticity of substitution is inversely related to risk aversion and to have that future growth rates have a positive impact on asset prices the intertemporal elasticity of substitution must be relatively high. For this reason many studies in finance have used alternative forms of utility functions. For example, Bansal & Yaron (2002) use Epstein-Zin preferences because allow to separate the risk aversion from the intertemporal elasticity of substitution. By choosing a high degree of risk aversion and a high intertemporal elasticity of substitution, they show that this type of preferences can generate high equity premiums without the need of large risk-free interest rates. Given that the goal of our paper is not to explain the equity premium, we abstract from risk aversion and use the simplest form of preferences in which future growth rates impact positively on asset prices, that is, the linear utility.

subject to

$$q = \beta E(1+g')\Big[c(\mathbf{s}') + q(\mathbf{s}')\Big] \tag{9}$$

$$\beta E(1+g')\Big[c(\mathbf{s}') + q(\mathbf{s}')\Big] \geq D(k, w(\mathbf{s})) \tag{10}$$

$$c(\mathbf{s}') \geq 0,\ q(\mathbf{s}') \geq 0 \tag{11}$$

Condition (9) is the promise-keeping constraint, (10) is the enforceability constraint (incentive-compatibility) and (11) imposes the non-negativity of the payments to the entrepreneur. The term $(1+g')$ derives from the detrending procedure. We have used the prime to denote the next period variable.

The function $S(\mathbf{s}, q)$ is the end-of-period surplus of the contract, net of the cost of capital. If we invest k—which is a cost—the discounted gross revenue paid in the next period is $(1/(1+r))R(k, w(\mathbf{s}))$. Therefore, the discounted profits are $-k + (1/(1+r))R(k, w(\mathbf{s}))$, which define the current return in the recursive formulation.

In the general formulation, the value promised to the entrepreneur is allowed to depend on the next period states. Coherently with the formulation of the surplus function, the aggregate states are given by the current growth in productivity g, the switching probability p, and the distribution (measure) of firms over q. The recursive problem can be solved once we know the distribution function (law of motion) for the aggregate states, which we denote by $\mathbf{s}' \sim H(\mathbf{s})$.

Denote by μ the Lagrange multiplier associated with the promise-keeping constraint (9) and denote by γ the Lagrange multiplier associated with the enforceability constraint (10). Conditional on the survival of the firm, the first order conditions are:

$$\left(\frac{1}{1+r}\right) R_k - 1 - \gamma D_k \ = \ 0 \tag{12}$$

$$\mu(\mathbf{s}') + \gamma - \mu \ = \ 0 \qquad\qquad \text{for all } \mathbf{s}' \tag{13}$$

$$\mu - \gamma \geq \ 0, \qquad\qquad (= \text{if } c(\mathbf{s}') > 0) \tag{14}$$

$$\beta E(1+g')\Big[c(\mathbf{s}') + q(\mathbf{s}')\Big] - q = 0 \tag{15}$$

$$q - D(k, w(\mathbf{s})) \geq 0 \qquad\qquad (= \text{if } \gamma > 0) \qquad\qquad (16)$$

Condition (14), combined with condition (13), implies that the payment to the entrepreneur $c(\mathbf{s}')$ is zero if the next period Lagrange multiplier $\mu(\mathbf{s}')$ is greater than 0. This has a simple intuition. Because μ decreases when the enforceability constraint is binding (see condition (13)), when $\mu(\mathbf{s}')$ reaches the value of 0, the enforceability constraint will not be binding in future periods, that is, $\gamma = 0$ for all possible realizations of $\mathbf{s}'$. In this case the firm will always employ the optimal input of capital $\bar{k}(\mathbf{s})$ as can be verified in (12). Therefore, when $\mu(\mathbf{s}') = 0$, the firm is unconstrained.

Before reaching the unconstrained status, however, the enforceability constraint (10) 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. Moreover, in those periods in which the enforceability constraint is binding, condition (16) is satisfied with equality (and zero payments to the entrepreneur, unless the unconstrained status is reached that period). Therefore, this condition will determine the growth pattern of the firm. The following proposition states these properties more formally.

Proposition 3.1 *There exists $\bar{q}(\mathbf{s})$ such that,*

(a) The function $S(\mathbf{s}, q)$ is increasing and concave in $q \leq \bar{q}(\mathbf{s})$.

(b) Capital input is the minimum between $k = D^{-1}(q, w(\mathbf{s}))$ and $\bar{k}(\mathbf{s})$.

(c) If $q \leq \beta E(1 + g')\bar{q}(\mathbf{s}')$, the entrepreneur's payment $c(\mathbf{s}')$ is zero.

(d) If $q > \beta E(1 + g')\bar{q}(\mathbf{s}')$, there are multiple solutions to $c(\mathbf{s}')$ and $\tau(\mathbf{s}')$.

Proof 3.1 *The recursive problem (8) is a contraction. Therefore, there exists a unique function $S(\mathbf{s}, q)$ that satisfies the Bellman equation. Moreover, the recursion preserves concavity which guarantees the concavity of the surplus function. The other properties derive directly from the first order conditions (12)-(16).* *Q.E.D.*

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

3.2.1 Initial conditions

After characterizing the surplus function, we can now derive the initial conditions of the contract. Assuming competition in financial markets, the initial contract solves:

$$\begin{aligned} q^0(\mathbf{s}) \;&=\; \max \;\; q \\ \text{s.t.} \;\; S(\mathbf{s}, q) - q \;&\geq\; \kappa \end{aligned} \tag{17}$$

The solution to this problem is unique if proposition 3.1 holds. In fact, the function $S(\mathbf{s}, q)$ is increasing and concave, and for $q \geq \bar{q}(\mathbf{s})$ it has a slope of zero. Therefore, above some q, the function $S(\mathbf{s}, q) - q$ is strictly decreasing in q. This implies that the solution is unique and satisfies the zero-profit condition $S(\mathbf{s}, q) - q = \kappa$.

The determination of the initial value of q is shown in Figure 6. The figure plots the value of the contract for the investor, $S(\mathbf{s}, q) - q$, as a function of q. The initial input of capital is given by the point in which the curve crosses the set up investment κ. This is the point that maximizes the value of the contract for the entrepreneur, without violating the zero-profit condition for the investor.

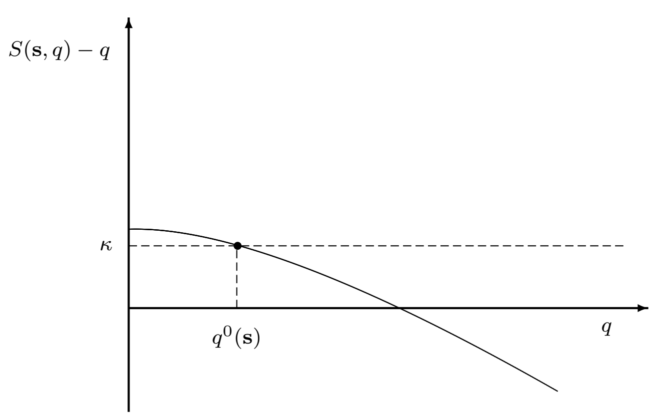


Figure 6: Initial conditions of the optimal contract.

3.2.2 General equilibrium

We provide here the definition of a recursive general equilibrium. The sufficient set of aggregate states are given by the current growth rate g, the switching probability p, and the distribution (measure) of firms over q, denoted by M. Therefore, $\mathbf{s} = (g, p, M)$.

Definition 3.1 (Recursive equilibrium) *A recursive competitive equilibrium is defined as a set of functions for (i) consumption $c(\mathbf{s})$ and labor $l(\mathbf{s})$ from workers; (ii) contract surplus $S(\mathbf{s}, q)$, investment $k(\mathbf{s}, q)$, consumption $c(\mathbf{s}, q)(\mathbf{s}')$ and wealth evolution $q(\mathbf{s}, q)(\mathbf{s}')$ for entrepreneurs; (iii) initial condition for a new firm $q^0(\mathbf{s})$; (iv) wage $w(\mathbf{s})$; (v) aggregate demand of labor from firms and aggregate supply from workers; (vi) aggregate investment from firms and aggregate savings from workers and entrepreneurs; (vii) distribution function (law of motion) for the next period states $\mathbf{s}' \sim H(\mathbf{s})$. Such that: (i) the household's decisions are optimal; (ii) entrepreneur's investment, consumption and wealth evolution satisfy the optimality conditions of the financial contract (conditions (12)-(16)), and the surplus satisfies the Bellman's equation (8); (iii) the wage is the equilibrium clearing price in the labor market; (iv) the capital market clears (investment equals savings); (v) the law of motion for the next period states is consistent with the individual decisions and the stochastic process for p.*

3.2.3 The impact of an asset price increase

We now consider the consequences of an increase in the value of new firms brought about by an increase in the probability that the economy will be in the high growth regime. We will state this experiment more precisely in our quantitative analysis. For the analysis in this section, any exogenous increase in the value of new firms would have equivalent consequences.

Figure 7 plots the value of the contract for the investor (before investing) as in Figure 6. As in the previous figure the initial value of q is at the point in which the investor's value crosses the set up investment κ. The second and higher curve follows from the increase in the value or surplus of the firm. 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

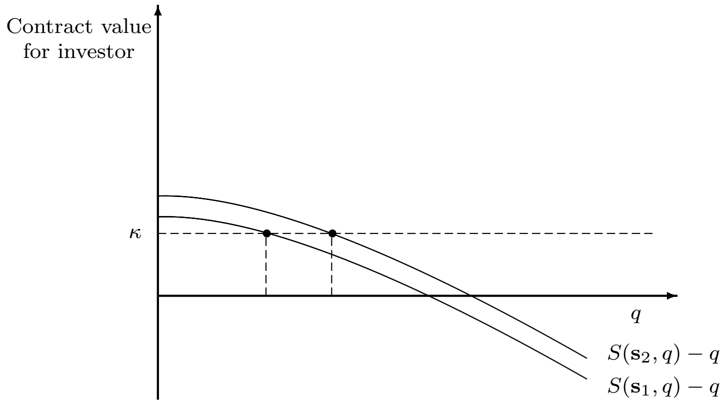


Figure 7: Impact of an asset price increase on the initial conditions of the contract.

firms $q = D(k, w)$), the price change increases the initial investment of new firms. This implies that the total stock of capital and employment increase.

The analysis underlying Figure 7 is based on the assumption that the wage rate remains constant. Although the supply of capital is elastic (given the risk neutrality assumption), the supply of labor is not perfectly elastic. This implies that the increase in the demand of labor induces an increase in the wage rate which reduces, but only partially, the initial increase in the stock of capital and in the demand of labor.

The asset price increase may also have important effects on the productivity of labor. On the one hand, entering firms are larger in size. On the other hand, the higher wage induces unconstrained firms to reduce their production scale. Consequently, the size distribution of firms becomes more concentrated. Given the concavity of the production function, this change in the size distribution of firms may generate an increase in the average productivity of labor. As described in Section 2, the quantitative importance of this effect will depend, among other things, on the labor supply elasticity.

In sum, an asset price increase driven purely by expectations of higher future growth rates has the potential to increase aggregate productivity without the need for an actual change in the technology level z. This mechanism operates through the relaxation in the financial constraints. If contracts were fully enforceable, there would be no financial constraints and, as seen in Section 3.1, there would be no effects of asset prices on the real economy.

3.3 Quantitative analysis

In this section we calibrate the model and study how the "expectations" of persistent higher future growth rates—the New Economy—impact on the macro performance of the economy. Let's start with the description and calibration of the growth process.

Specification and calibration of the growth process: The exogenous states are given by the current growth rate in the economy wide level of technology $g_z \equiv (z-z_{-1})/z_{-1}$ and the switching probability p. We denote the exogenous states by $x = (g_z, p)$. These exogenous states can be interpreted as shocks to the economy. The evolution of p is determined by the probability distribution $\Gamma(p' \,|\, p, g_z')$.

The growth rate g_z is restricted to take two values, that is, g_z^L and g_z^H. We assume that the switching probability p also takes two values. The first value is zero and the second is denoted by $\overline{p}$. Given that p can take only two values, there are four possible exogenous states or shocks: $x_1 = (g_z^L, 0)$, $x_2 = (g_z^L, \overline{p})$, $x_3 = (g_z^H, 0)$, $x_4 = (g_z^H, \overline{p})$. The stochastic properties of these four states are governed by a four-dimension transition probability matrix. To construct this matrix we make the following assumptions about $\Gamma(p' \,|\, p, g_z')$. First, conditional on remaining on the same growth regime, the transition probability matrix for $p \in \{0, \overline{p}\}$ is:

$$\Gamma(p' \,|\, p, g_z' = g_z) \;=\; \begin{bmatrix} 1-\rho & \rho \\ \rho & 1-\rho \end{bmatrix}$$

If the economy switches to a different growth regime, the transition probability matrix is:

$$\Gamma(p' \,|\, p, g_z' \neq g_z) \;=\; \begin{bmatrix} 1 & 0 \\ 1 & 0 \end{bmatrix}$$

This implies that if the economy switches to a new growth regime, the initial probability of switching back to the old regime is zero. This assumption makes a regime switch more persistent. Before the economy can switch back to the old regime, it has to reach the state with $p = \overline{p}$.

Using the above specifications, the transition probability matrix for the four states $x = (g_z, p)$ (joint distribution of g_z and p) is equal to:

$$\text{prob}(x'|x) = \begin{bmatrix} (1-\rho) & \rho & 0 & 0 \\ \rho(1-\overline{p}) & (1-\rho)(1-\overline{p}) & \overline{p} & 0 \\ 0 & 0 & (1-\rho) & \rho \\ \overline{p} & 0 & \rho(1-\overline{p}) & (1-\rho)(1-\overline{p}) \end{bmatrix}$$

This matrix depends only on two parameters: ρ and $\overline{p}$. In our simulation exercise we assume that $\rho \approx 0$ and we consider several values of $\overline{p}$. According to this parameterization, as long as the economy remains in the same growth regime, the switching probability $p \in \{0, \overline{p}\}$ is very persistent. We interpret the first state $x_1 = (g_z^L, 0)$ as the state prevailing during the period 1972:2-1995:4 and the second state $x_2 = (g_z^L, \overline{p})$ as the state prevailing during the period 1995:4-2000:4. Therefore, our assumption is that the actual growth rate of technology has not changed during the last part of the 1990s. What has changed is the probability with which the economy could have switched to the higher growth regime.

Consistent with this interpretation, we take the growth rate in trend productivity during the period 1972:2-1995:5 to calibrate the growth rate in the low growth regime g_z^L. As reported in Table 1, the trend growth in labor productivity during this period was 1.42% per year. Therefore, we set $g^L = (g_z^L)^{1/(1-\theta\epsilon)} = 0.0142$. The higher rate g_z^H, instead, is interpreted as the growth rate in the "New Economy". To calibrate g_z^H we use the citation in Ip & Schlesinger (2001). According to this article, the New Economy was believed to grow at rates exceeding the previous rates by 1 or even 1.5 percent. Accordingly, we set $g^H = (g_z^H)^{1/(1-\theta\epsilon)} = 0.0292$.

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 is $\alpha = 0.99$. The low value for the interest rate is justified by the lower equity premium observed in most recent years.

The fraction of agents with entrepreneurial skills e determines the average employment size of firms: larger is e and larger is the equilibrium wage rate and smaller is the employment size of firms. We set e such that the average employment size of firms is 500 workers. However, the choice of a different average size of firms does not affect the results.

The detrended disutility from working takes the form $\varphi(l) = \pi \cdot l^{\nu}$ and the supply of labor is governed by the first order condition $\nu\pi l^{\nu-1} = w\alpha/(1+r)$. The elasticity of labor with respect to the wage rate is $1/(\nu - 1)$. Therefore, we can pin down the parameter ν using existing estimates of the labor elasticity. Blundell & MaCurdy (1999) provide an extensive survey of studies that estimate 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, we use a labor elasticity of 0.5 which implies a value of $\nu = 3$. In the sensitivity analysis, however, we will consider alternative values. After fixing ν, the parameter π is chosen so that one third of available time is spent working. This requires an iterative procedure. After fixing π and solving for the steady state equilibrium we check whether the equilibrium labor supply is 1/3. However, given the simple form of the utility function the choice of this calibration target is irrelevant for the results.

The production function is specified as $(k^{\epsilon}l^{1-\epsilon})^{\theta}$. Atkeson, Khan, & Ohanian (1996) argue that a value of $\theta = 0.85$ is reasonable parameterization of the return to scale parameter. This is also the value used by Atkeson & Kehoe (2001). The parameter ϵ, then, is set so 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, we use this condition to calibrate ϵ. Then, using the first order condition for the optimal input of capital (which is satisfied for unconstrained firms), we can express the depreciation rate as:

$$\delta = \frac{\theta\epsilon}{K/Y} - r \tag{18}$$

Using a capital-income ratio of 2.5 and the values of the other parameters chosen above, the value of δ is equal to 0.08. Notice that the economy-wide capital-income ratio will not be exactly 2.5 because in the economy 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 production technology becomes unproductive with probability $1 - \phi = 0.04$. Associated with the 1 percent probability that the entrepreneur dies, the exit probability of firms is about 5 percent. This is consistent with several empirical studies about firms' turnover as in Evans (1987).

There are two other parameters that need to be calibrated: the default parameter λ and the set up investment κ. These two parameters are important to determine the initial size of new firms. Larger the values of these two parameters and smaller is the initial size of new firms. The parameter λ, in particular, is especially important to determine the feasible range of size distribution of firms. We have seen that the investor value is concave for all values of q and k. However, it is decreasing only for k above a certain threshold. This threshold determines the possible range in the size distribution of firms because the size of firms will never be smaller than this threshold (the contract would not be free from renegotiation). The important point is that this threshold declines as we increase λ. Therefore, in order to allow for a sufficient heterogeneity in the size distribution of firms we have to set λ sufficiently large. According to OECD (2001), the average size of entrant firms in the U.S. business sector is about 15% the size of incumbent firms. Therefore, we calibrate λ and κ such that the capital used by entrant firms is 15% the capital used by incumbent firms. To make this possible, λ must take at least the value of 3 (otherwise the initial size of new firms cannot be that small). After setting $\lambda = 3$, we determine the value of κ such that k_0 is exactly 15% the capital of incumbent firms.[8] The full set of parameter values are reported in table 2.

Table 2: Parameter values.

Growth regimes	$g \in \{0.0142, 0.0292\}$
Transition probability parameter	$\rho \approx 0$
Intertemporal discount rate	$r = 0.02$
Disutility from working $\varphi(l) \equiv \pi \cdot l^{\nu}$	$\nu = 3$
	$\pi = 0.002$
Survival probability of agents	$\alpha = 0.99$
Survival probability of projects	$\phi = 0.96$
Production technology $(k^{\epsilon} l^{1-\epsilon})^{\theta}$	$\theta = 0.85$
	$\epsilon = 0.294$
Depreciation rate	$\delta = 0.08$
Set up investment	$\kappa = 0.283$
Default parameter	$\lambda = 3$

[8]Larger values of λ (and smaller values of κ) would affect the speed of convergence of firms to the unconstrained status but it would not affect in a significant way the main results of the paper. However, we have some constraints on how large λ could be. If λ is too large, then the value of defaulting becomes greater than the surplus generated by the firm. Obviously this cannot be possible.

Simulation results: Our computational exercise consists of simulating the artificial economy for a particular sequence of exogenous states (shocks). More specifically, we solve the model for the following realizations of exogenous states (shocks):

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

In words, we assume that the economy has been in the state $x_1 = (g_z^L, \underline{p})$ 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, the switching probability increases to $\overline{p}$ and the economy switches to the new state $x_2 = (g^L, \overline{p})$. We will then consider a sequence of realizations of this state and we compute the transition to the new long term equilibrium associated with x_2. Therefore, after the arrival of the signal the economy remains in the low growth regime for several periods even though in each period there is a positive probability of transiting to the New Economy. Although these are very extreme assumptions, they capture the main idea of the paper, that is, the fact that in the 1990s the likelihood of the New Economy increased. This shift in expectations was driven by the rapid diffusion of information and communication technologies. The assumption underlying the numerical exercise is that the economy did not actually switch to this new regime. This assumption allows us to isolate the mechanism described in the paper, based on the expectation mechanism, from a direct source of productivity improvements.

Figures 8 and 9 plot the detrended responses of the economy after the unanticipated and persistent arrival of the signal $\bar{p}$. As stated above, the responses are constructed after a sequence of $g_z = g_z^L$, which means that the economy never switches to the high growth regime (although this can happen in any period with probability $\bar{p}$). Because the economy never switches to the high growth regime, the trend growth is $g^L = g_z^1 1 - \theta\epsilon = 0.0142$. Several values of $\bar{p}$ are considered.

The plots in Figure 8 can be interpreted as the sequential set of events through which the expectations about the New Economy leads to the improvement in the productivity of labor. First, the higher value of p increases the value of firms (plot a) and generates a stock market boom. The asset price boom is modest in quantitative terms. However, in the next section we will change the model slightly and we will be able to generate a larger asset price impact. For simplicity, however, we postpone the description of this extra feature to the next section after we have described the main quantitative feature of the simplest model.

After the stock market boom new firms get higher initial financing and hire more labor (plot b). With the exception of the first period, this implies that the demand of labor increases and pushes up the wage rate (plot c).[9] A higher wage rate, then, induces unconstrained firms to reduce employment (plot d). Also, the higher wage rate induces a substitution of labor with capital and increases the intensity of capital (plot 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 $\bar{z}(k^{\epsilon}l^{1-\epsilon})^{\theta}$, the aggregate productivity of labor can be written as:

$$\text{LabProd} = \bar{z}\left(\frac{K}{L}\right)^{\theta\epsilon}\sum_i \omega_i L_i^{\theta-1} \tag{19}$$

where L_i is the labor employed by firm of type i and ω_i is the share of labor employed by all firms of type i. The capital-labor ratio is the same for all firms and depends on the wage rate. Firms of different types differ only in the scale of production, that is, the level of employment. Taking logs and first difference we get:

$$\Delta\text{log(LabProd)} = \Delta\text{log}\bar{z} + \theta\epsilon\Delta\text{log}\left(\frac{K}{L}\right) + \Delta\text{log}\left(\sum_i \omega_i L_i^{\theta-1}\right) \tag{20}$$

The first element on the right-hand-size is zero because $\bar{z}$ does not change in our simulation exercise. The second element is the contribution of capital

[9] In the first period the demand of labor decreases because old firms that are still financially constrained reduce their investment. This investment reaction of constrained old firms derives from the features of the optimal contract. In this contract investment is state contingent. When the economy is in an expansionary path and the wage rate will eventually increase, the optimal size of firms decreases. On the other hand, when the economy is in a recession path and the wage rate decreases, the optimal size of firms tends to increase. This implies that the growth incentive for the firm is lower when the economy is expanding. Anticipating this, the optimal contract recommends higher levels of investments when the economy is in a recession path and lower levels of investment when the economy is in an expansionary path. The negative investment effect coming from existing constrained firms will be overturned later on by the entrance of new firms.

deepening while the third is the contribution of the labor reallocation. These two contributions to the productivity of labor are shown in plots g and h. About half of the productivity increase is generated by the reallocation effect.

Notice that if we use a constant return-to-scale production function to evaluate the contribution of the different factors to the productivity change, the last term of equation 20 would be zero because $\theta = 1$. Consequently, the reallocation effect would be mistakenly attributed to an exogenous increase in $\bar{z}$ or Solow residuals, that is, $\Delta\log\bar{z} = \Delta\log\left(\sum_i \omega_i L_i^{\theta-1}\right)$.

Figure 9 shows the impact of the higher p on other macroeconomic variables. Again, with the exception of the first period, capital, employment and production all get a positive and persistent impulse from the higher switching probability. Moreover, larger is the signal and larger is the impact on the economy. It is also interesting to observe that a small value of $\bar{p}$ can have significant effects on the economy. This is because the signal is persistent. Even if there is only 10 percent probability of switching to the New Economy, this probability is present in every period and once the economy has switched, it will remain in the high growth regime with high probability. The last panel of Figure 9 plots the fraction of firms that are not financially constrained. As can be seen, this fraction increases with the signal. This is another way to show how the stock market boom relaxes the tightness of financial constraints. Not only we have that new firms get greater initial financing, but we also have that the fraction of firms that are unable to get full financing decreases.

3.4 Dependence of asset prices on growth

One weak aspect of the model presented in the previous section is the inability to generate a large stock market boom as the one observed in the second half of the 1990s. Prices have more than doubled during this period. The reason our model can not generate such large asset price booms is because firms' profits are discounted at very high rates due to the high mortality of firms. To see this point, consider the following formula that defines the steady state price of a firm once it reaches the unconstrained status:

$$P = \frac{d}{1 - \left(\frac{\phi}{1+r}\right)(1+g)} \tag{21}$$

where d are the detrended values of dividends and they are constant in the steady state. The parameter ϕ is the survival probability of firms, r is the interest rate and g is the growth rate of the economy. The term $\phi/(1+r)$ is the discount factor used to discount dividends and it is multiplied by $1+g$ because dividends are detrended. As is well known in asset price studies, higher is the discount factor, and larger is the impact of an increase in g on the price of assets. In fact, as the discount factor approaches 1, the impact of an increase in g tends to infinity. In our framework the discount factor is $\phi/(1+r)$. But even if the interest rate is very small, the parameter ϕ can not be close to one because the mortality of firms is relatively high. In our calibration $\phi/(1+r) \approx 0.93$ and with this value, changes in g have a modest impact on P.

Even if the average mortality of firms is high in the data, this rate tends to decrease with age. We can use this idea to differentiate the survival probability of new firms from old and mature firms. In particular, old firms face a much smaller probability of exit. Because a higher survival probability translates in higher discount factors, for these firms a change in the growth rate will have a much larger impact on prices. If the fraction of mature firms in the economy is large, then the whole market valuation will be more sensitive to g.

To implement this idea we assume that ϕ can take two values, $\underline{\phi}$ and $\overline{\phi}$, which $\underline{\phi} < \overline{\phi}$. When firms are born, their initial survival rate is $\underline{\phi}$. Over time, however, these firms may become mature with some probability. In that case their survival probability becomes $\overline{\phi}$. Figure 12 reports the impulse responses after an increase in the switching probability for this new version of the economy. The calibration of the survival process is as follows. We set $\underline{\phi} = 0.91$ and $\overline{\phi} = 0.01$. 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 probability 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 OECD (2001). According to this source, only 50% of entrant firms are still alive after 7 years which is consistent with the yearly 10% probability of exit assumed for new entrant firms. After parameterizing $\underline{\phi}$ and $\overline{\phi}$, the probability that a firm becomes mature is set such that the average exit rate is 5 percent (this was the value used in the previous calibration). All the other parameters are as in the previous version of the model with the exception of κ. The value of κ is changed so that the initial size of entrant firms is still 15% the size of incumbent firms.

As can be see from Figures 10 and 11, this new version of the model generates a dynamics which is qualitatively similar to the dynamics of the previous version. Quantitatively, however, this model generates a much larger increase in the stock market value. The increase in the market valuation of firms is now in the order of 50 percent. The impact on labor productivity is also higher.

Consistent with the intuition provided by the price equation (21), we can generate even larger impacts on the stock market if we reduce the interest rate. Figure 12 plots the stock market value and other variables for different values of the interest rates. If we reduce the interest rate to 1.5%, we can generate a stock market boom that is close to 100 percent. When the interest rate is 3%, instead, the stock market boom is much smaller. Notice that even if the impact on the stock market is very sensitive to the interest rate, the impact of the market boom on productivity does not change much. This is because the stock market boom obtained in the baseline model already eliminates almost all the financial restrictions faced by new firms. The economy then, is very close to a frictionless economy and further increases in the stock market have a modest impact on the real sector of the economy.

3.5 Sensitivity analysis:

The impact of the higher p on the productivity of labor depends on the elasticity of the labor supply and the curvature of the production function. To show the importance of the elasticity of labor, Figure 13 plots the impulse responses of the stock market, hours worked and productivity for different values of the parameter ν. In these impulse responses the value of the switching probability is $\bar{p} = 0.2$. These graphs confirm the intuition provided in the previous sections. When labor is not very elastic, a positive signal has a larger effect on productivity but a smaller effect on aggregate employment and production.

Figure 14 conducts a sensitivity analysis with respect to the parameter θ. In changing θ we also change λ and κ so that the initial size of new firms is the same as in the previous calibration before the increase in p. When θ is small and the production function is very concave, the higher value of p generates a higher productivity gain and a larger impact on the aggregate economy. This confirms the intuitions provided in Section 2.

4 Additional empirical evidence

In this final section we provide some empirical evidence in support of the reallocation mechanism underlying the productivity gains emphasized in the previous sections. The main feature of this mechanism is that labor has been reallocated to firms that are more financially constraints. To verify this mechanism we would need cross-sectional panels of firms which however are not available for the years under consideration. However, we have data on the size distribution of employers (firms). As long as there is some correlation between the size of employers and the tightness of financial constraints, we can use the size of firms as a proxy for the tightness of financial constraints.

The County Business Patterns published by the Census Bureau contains annual data on the number of workers employed by firms of a certain size. Most of the country's economic activity is covered, with the exception of data on self-employed individuals, employees of private households, railroad employees, agricultural production employees, and most government employees. Firms are grouped into 3 size classes in terms of number of employees: firms with less than 20 employees; firms with less than 100 employees; firms with less than 500 employees. Figure 15 reports the percentage of firms and the employment share in each of these three size classes over the period 1988-99. As can be seen, the number of firms and the employment share of smaller firms (the left section of the distribution) have been declining during the 1990s. Furthermore, this tendency seems to accelerate in the second half of the 1990s.

Figure 15 points out that the left tail of the distribution of firms and employment in small firms has shrunk, which is consistent with out reallocation mechanism. Do we also observe that the right tail of the distribution has shrunk? In other words, do we observe that the employment share of extremely large firms—let's say the 50 largest or the 100 largest firms—has declined during this period? Unfortunately we do not have data for each year during the 1990s and for the whole economy. However, we have some concentration indices for the manufacturing sector and for two years: 1992 and 1997. These indices are constructed using data from the 1992 and the 1997 Economic Census (which is conducted with a 5 years frequency). These indices are reported in Table 3 for five classes of manufacturing firms: the 50 largest; the 51st to 100th largest; the 101st to 150th largest; the 151st to 200th largest; the 201st largest and smaller. The rank of firms is based on value added.

Table 3: Share of Industry Statistics for Companies Ranked by Value Added.

	Total employees	Production workers Total	Production workers Hours	Production workers Wages	Value added	New capital expenditures
	1992 Economic Census					
50 largest	13.0	12.8	12.9	19.3	23.7	21.8
51st to 100th largest	4.5	4.3	4.4	5.4	8.4	10.8
101st to 150th largest	3.9	4.3	4.4	4.9	5.5	6.8
151st to 200th largest	2.8	3.0	3.0	3.5	4.0	5.7
201st largest and smaller	75.8	75.5	75.3	66.8	58.3	55.0
	1997 Economic Census					
50 largest	11.7	10.6	11.1	16.8	24.0	21.3
51st to 100th largest	4.4	4.2	4.4	5.2	7.7	7.3
101st to 150th largest	3.6	3.7	3.7	4.4	5.2	5.3
151st to 200th largest	2.8	2.9	3.0	3.3	3.8	4.1
201st largest and smaller	77.5	78.6	77.7	70.4	59.3	62.0

Source: *Concentration Ratios in Manufacturing: 1992 and 1997 Economic Census*

A quick inspection of the table reveals that the employment share of the 1997 largest firms has decreased relative to 1992. This tendency can also be observed in terms of shares of new capital expenditures. Therefore, according to this table the right tail of the size distribution of manufacturing firms seems to have shrunk in relative terms. This pattern is consistent with our reallocation mechanism. There is also another pattern shown by the table which is worth emphasizing. Although the share of employment of the 50 largest firms has decreased, the share of value added has not decreased. At the same time, when we look at the class of smaller firms, the increase in the value added share is smaller than the increase in employment share. This seems to suggest that the labor productivity of the largest firms has increased relative to the productivity of smaller firms which is perfectly consistent with our reallocation mechanism.

To summarize, although the evidence provided in this section is not a rigorous proof of the importance of our reallocation mechanism, nevertheless it is fully consistent with it.

Before closing we would like to relate the medium-term dynamics of unemployment with the dynamics in the productivity of labor. According to our model, when employment is high (and unemployment low), the productivity of labor should grow faster. It is interesting to notice that this pattern is observed in the data as shown in Figure 16, which is taken from Staiger, Stock, & Watson (2001). This figure plots the trend values of unemployment and labor productivity growth during the last 4 decades, constructed using a low pass filter. See Staiger et al. (2001) for more details. This figure shows that the trend in unemployment moves in the opposite direction to the trend in the growth rate of labor productivity which is consistent with the mechanism emphasized in this paper. In our story, an important driving force underlying these patterns is the movement in the stock prices as shown in figure 2.

5 Conclusion

This paper develops a general equilibrium model with financial market frictions in which stock market booms can generate an economic expansion with substantial productivity gains. This expansion would not arise in absence of financial frictions. The reaction of the economy to a stock market boom is consistent with the 1990s expansion of the US economy characterized by higher investment, higher productivity, higher employment and higher production. This interpretation of the U.S. expansion may coexist with the more traditional view which assigns a direct role to technological improvements related to information and communication technologies as in Cooley & Yorukoglu (2001). However, most of the studies investigating the importance of information and communication technologies conclude that these technologies can explain only part of the productivity improvement observed in the second half of the 1990s. This paper provides a complementary explanation for the productivity gain which is coherent with the view of more recent studies. These studies emphasize the "business reorganization" induced by greater competition. Our view is that the driving force of this greater competition was the asset price boom experienced by the U.S. economy in the second half of the 1990s.

Appendix: computation of equilibrium

Equations (12)-(16) with the entry condition $q + \kappa = S(\mathbf{s}, q) = -k + R(k, w)/(1+r) + \beta E(1+g')S(\mathbf{s}', q')$ provide the dynamic conditions to solve the model. If we knew $E(1+g')q(\mathbf{s}')$ and $E(1+g')S(\mathbf{s}', q')$, these conditions would be sufficient to solve the model. The problem is that we do not know $E(1+g')q(\mathbf{s}')$ and $E(1+g')S(\mathbf{s}', q')$. Therefore, the basic idea behind the numerical procedure is to parameterize these two functions and then solve the model on a grid of values for μ. The parameterization we use depends on the particular problem we try to solve. In the computation of the equilibrium we assume that $\rho = 0$ and $\underline{p} = 0$. Therefore, when the economy gets the new signal $\overline{p}$, the economy continues to receive this signal with probability 1 as long as the economy does not switch to the high growth regime. Moreover, if the economy switches to the high growth regime, the switch will be permanent. The equilibrium computed under these assumptions is an approximation of the case in which ρ and $\underline{p}$ are not very different from zero as assumed in the calibration section.

Steady state: A steady state is obtained when $p = 0$ forever. Given the steady state wage, we can solve the contract on a grid of points of q. Let $q_n = \beta^{n-1}\overline{q}$, where $\overline{q}$ is the entrepreneur's value for which the firm is unconstrained. Because in the steady state q grows at rate $1/\beta - 1$ (remember that for constrained firms $q = \beta(1+g)q'$, starting from any q_n, the entrepreneur's value will always be in one of the grid points. We start at $q_1 = \overline{q}$ and we solve the contract in each grid point backward. The values of q' and $S(q')$ are given by the solutions found in the previous grid point.

Post-switching transition: The basic exercise consists of solving for the equilibrium after the arrival of a positive signal about the New Economy. A positive signal implies that in each period there is a probability that the economy switches permanently to the high growth regime. The first step then is to solve for the equilibrium in the event in which the economy switches permanently to this new regime. First let's observe that, for any given states, there is a monotone (decreasing) relation between the promised utility q and the Lagrange multiplier μ. This relation is represented by the function $q = \psi(\mathbf{s}, \mu)$. Given this monotone relation between q and μ, it will be convenient to use μ as a state variable for the contract instead of q. The advantage derives from the fact that once the firm reaches the unconstrained status, μ remains constant at zero while $\bar{q}(\mathbf{s})$ continues to fluctuate. The state of the economy, then, is the distribution of firms M over the variable μ.

To solve for this transition, we guess the sequences of next period values q' and S' at each grid point of μ and for 100 periods. These 100 periods are sufficient for the economy to converge to the new steady state. Given these guesses, we solve the model in all 100 periods. As part of the solution we get q and S for each simulation period. These will be used to update the sequences of guesses for q' and S', until convergence.

The solution of the post-switch transition is necessary to solve for the pre-switching transition. Because in the pre-switching transition there is a positive probability that the economy undertakes the New Economy path, in structuring the optimal contract agents need to predict what will happen after the switching. However, solving for any possible initial distribution of firms becomes computationally impossible. Therefore, we need to approximate the initial conditions after switching. We take the following strategy. First we assume that the distribution of firms is well approximated by some of its moments. In particular, we consider two moments: the fraction of firms with μ greater that a certain threshold and the fraction of firms with μ smaller than the threshold but greater than zero. We then construct a grid for each of these two moments. To each point of this two-dimensional grid corresponds a re-scaling of the steady-state distribution. For each grid point we solve for the whole transition and determine the (vector) values of q and S at the beginning of the transition. We will denote by q_H and S_H these initial values. These values will be used in the solution of the pre-switching transition described below.

Pre-switching transition: After the arrival of a positive signal, the economy starts a transition path to a new long-term equilibrium. This new equilibrium is obtained by assuming that p remains constant and the economy never switches to the high growth regime. However, even if the economy never switches to the high growth regime, agents expect that this can happen with probability p. Therefore, in solving for the optimal contract, we have to predict what happens if the economy switches. More specifically, if the state of the contract is μ, what will be the value of q'_H and S'_H once the economy has switched? These values will be extrapolated from the calculation described above.

We guess the sequences of $E(1+g')q(\mathbf{s}')$ and $E(1+g')S(\mathbf{s}',q')$, in each grid point, and for 100 periods. These 100 periods are sufficient for the economy to converge to the new long-term equilibrium. Given these guesses, we solve the model in all transition periods. At this point we update the guesses for $E(1+g')q(\mathbf{s}')$ and $E(1+g')S(\mathbf{s}',q')$. First notice that these terms can be written as $E(1+g')q(\mathbf{s}') = p(1+g_H)q'_H + (1-p)(1+g_L)q'$ and $E(1+g')S(\mathbf{s}',q') = p(1+g_H)S'_H + (1-p)(1+g_L)S'$, where q_H and S_H denote the entrepreneur's value and the surplus if the economy switches to the high growth regime. To update q' and S' we use the solution for q and S. The values of q_H and S_H, instead, will be extrapolated from the calculation of the initial conditions in the post-switching transition. The economy starts the new period with a certain distribution of firms over μ. Notice that this distribution does not depend on whether the economy has switched or not. Given this distribution we compute the two moments of the distribution previously described. The value of q_H and S_H are then determined by interpolating the values of q_H and S_H on the grid points of these two moments as calculated above (post-switching transition). The process is repeated until convergence.

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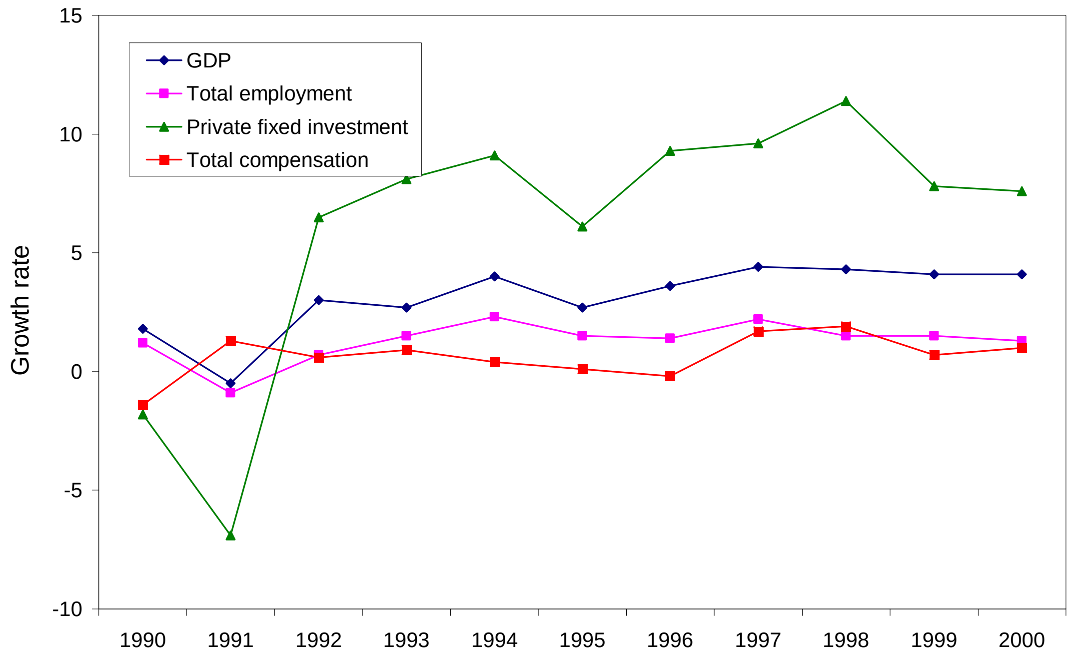
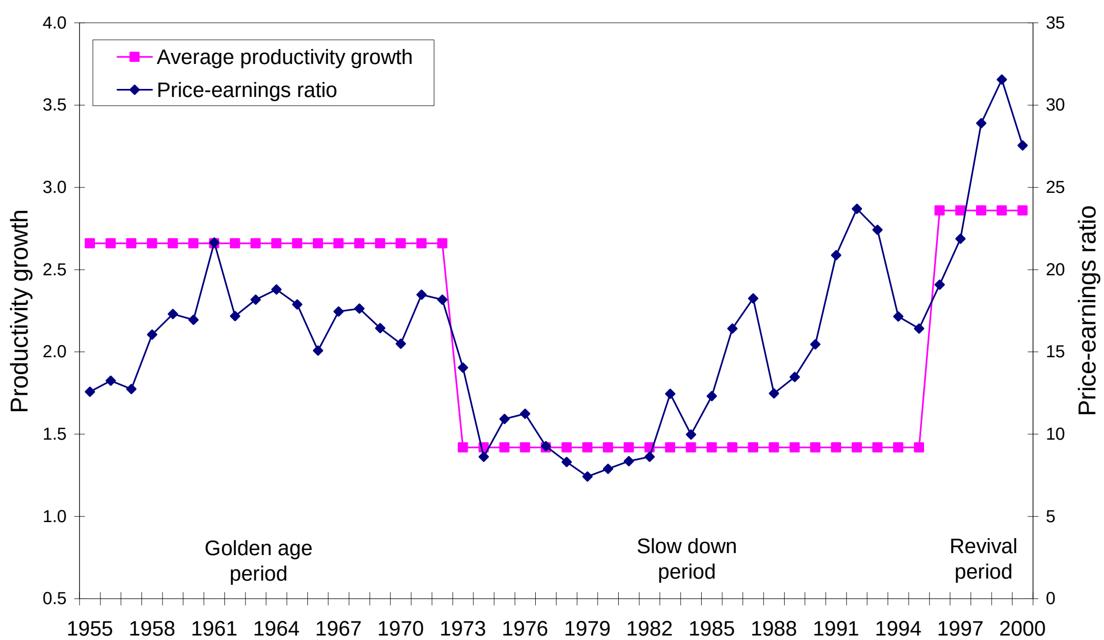
Figure 1 - Growth of macroeconomic variables



Source: Economic Report of the President (2002)

Figure 2 - Productivity growth and price-earning ratio



Source: Economic Report of the President (2002)

Figure 3a - Yearly data

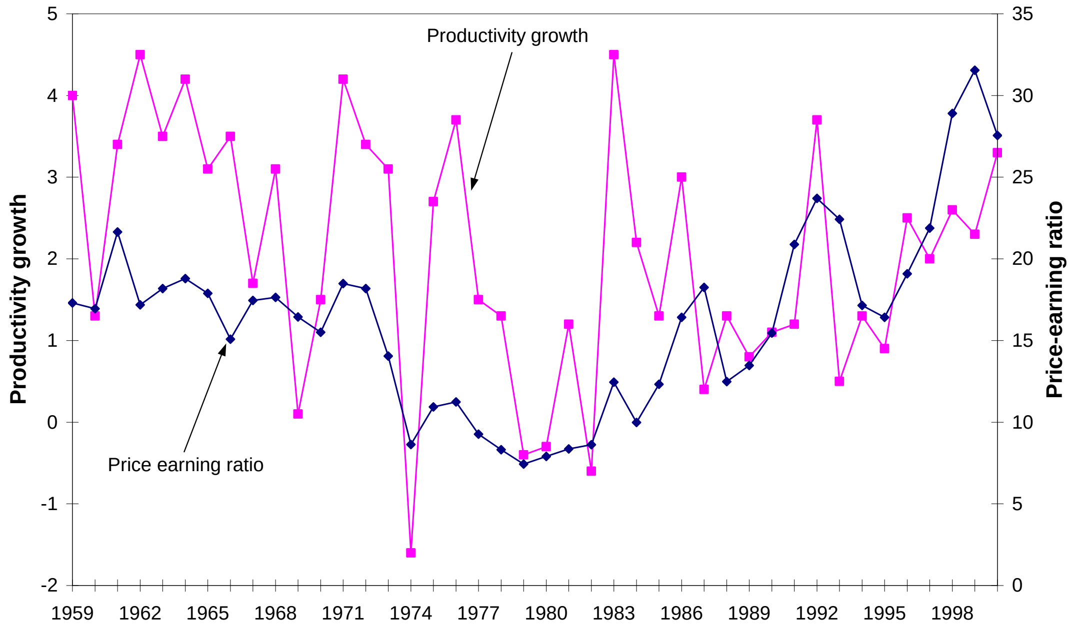


Figure 3b - Trend data

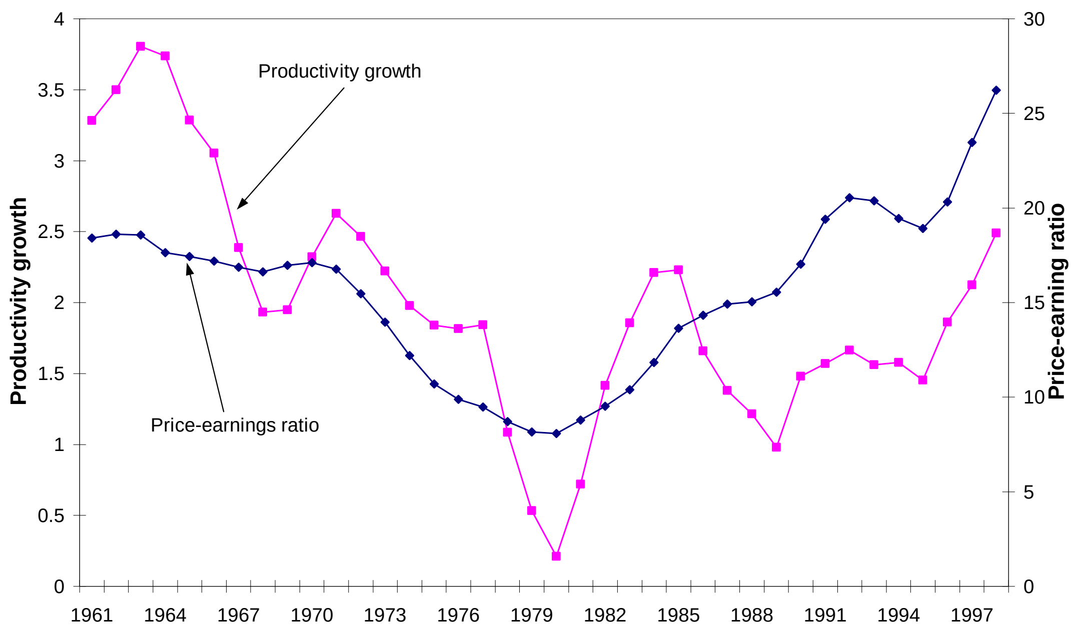
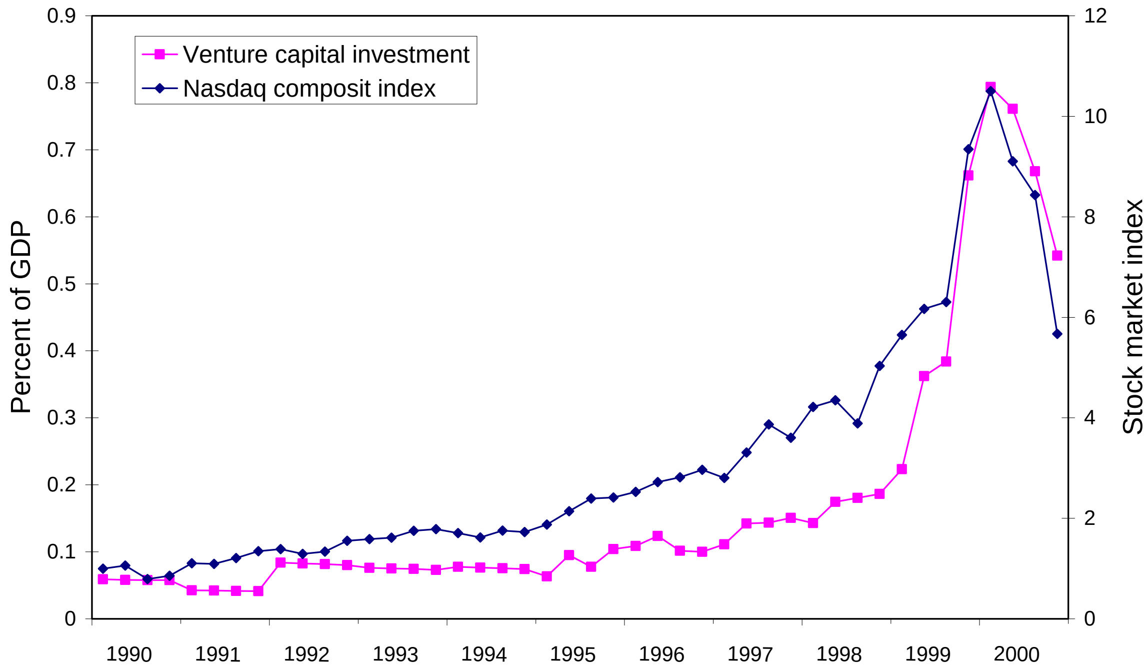


Figure 4 - Stock market and Venture Capital



Source: CRSP database and PricewaterhouseCoopers

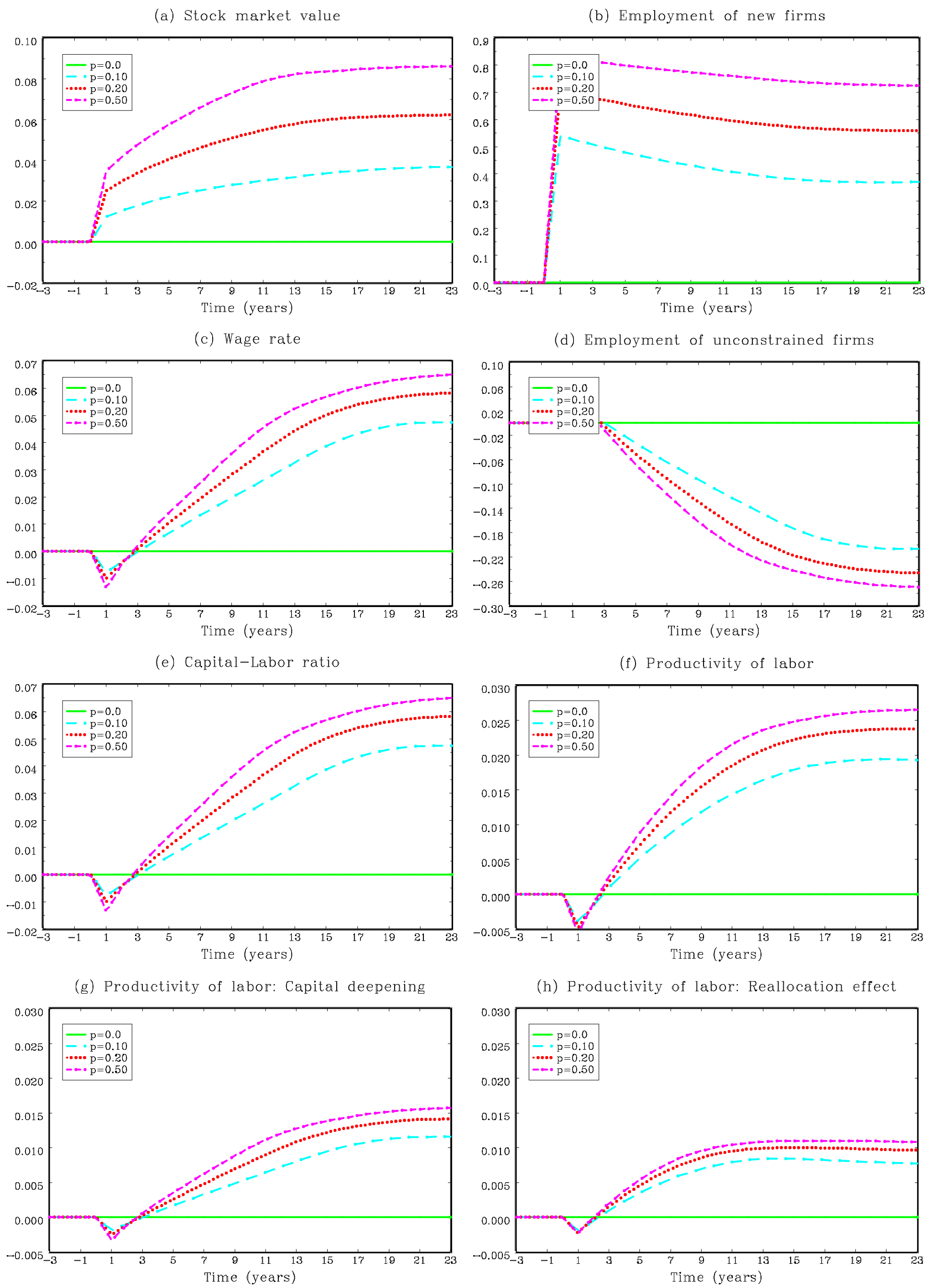


Figure 8: Impulse responses after the increase in the switching probability p.

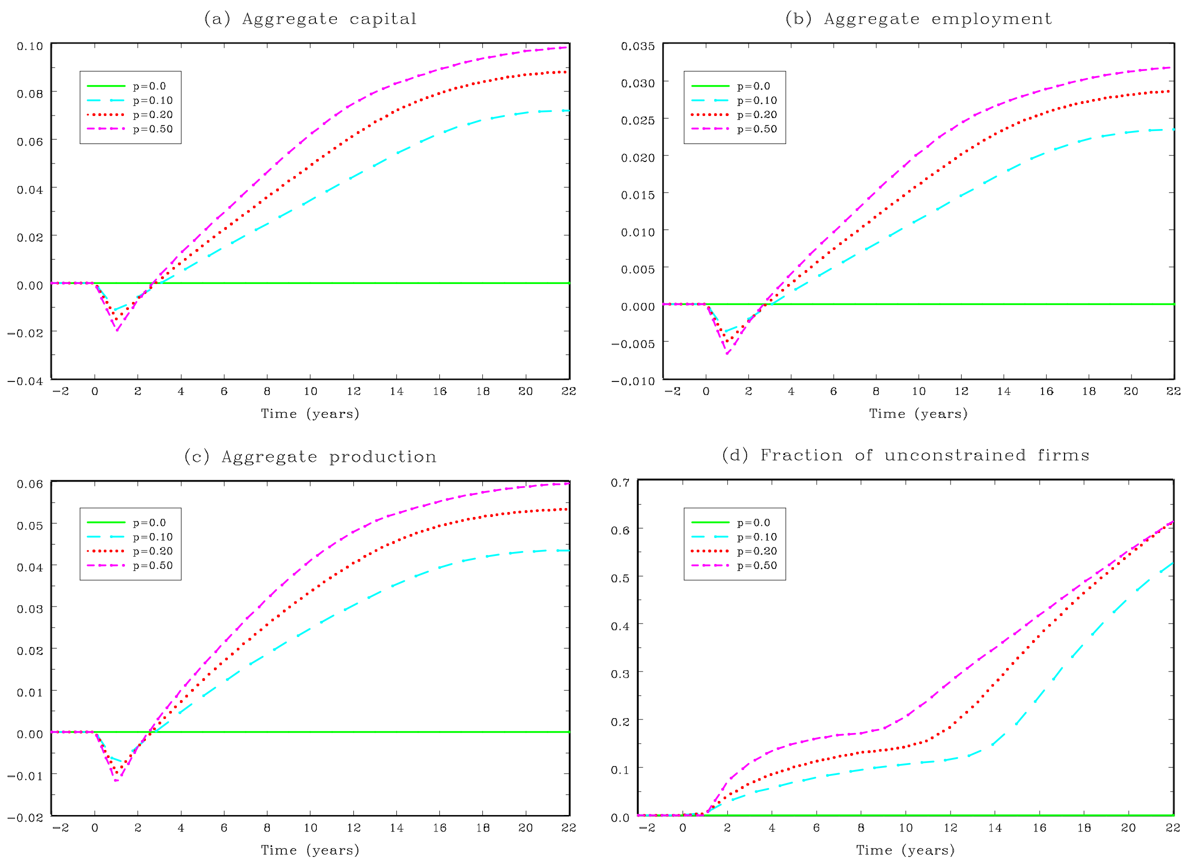


Figure 9: Impulse responses after the increase in the switching probability p.

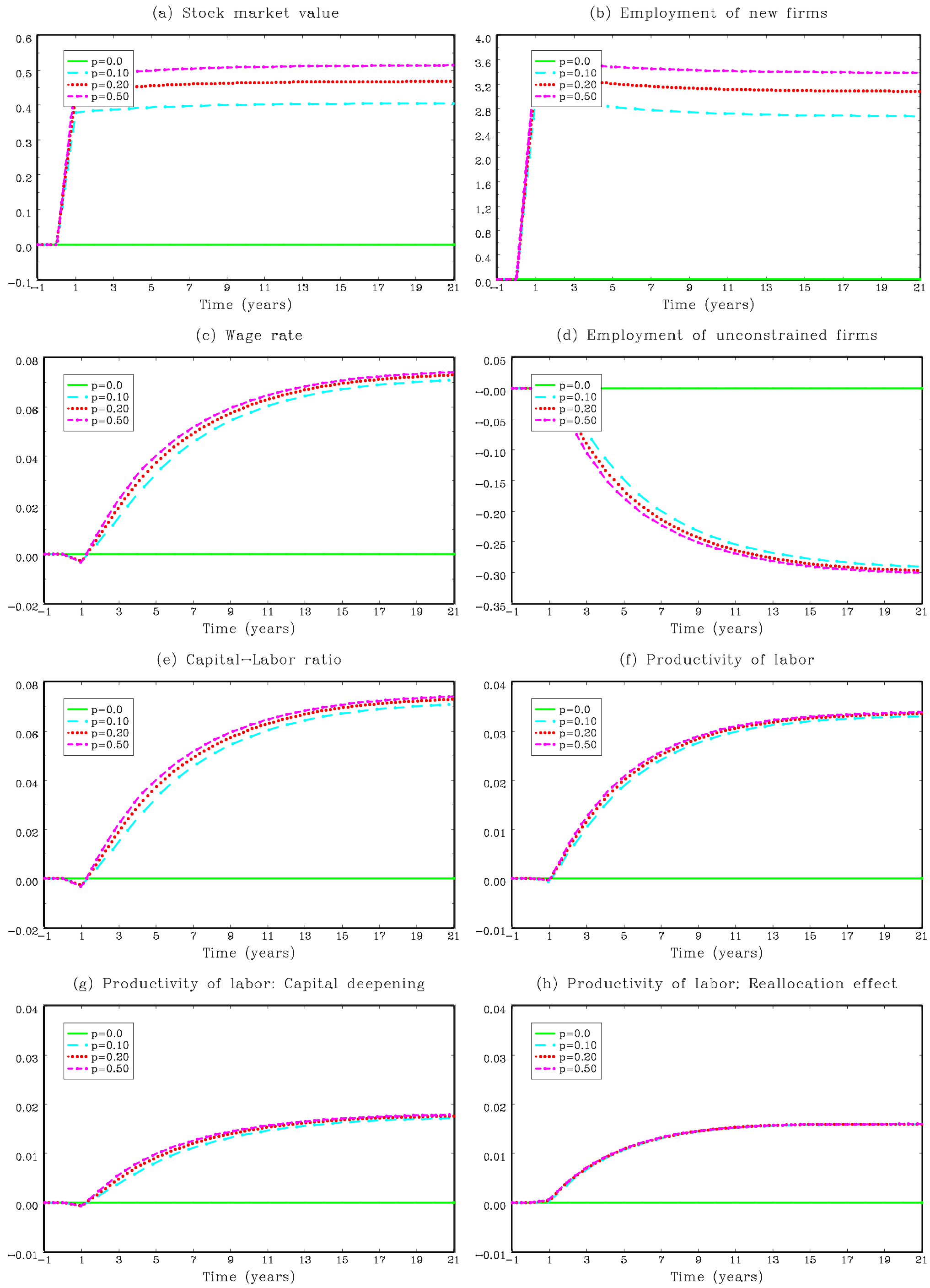


Figure 10: Impulse responses after the increase in the switching probability p.

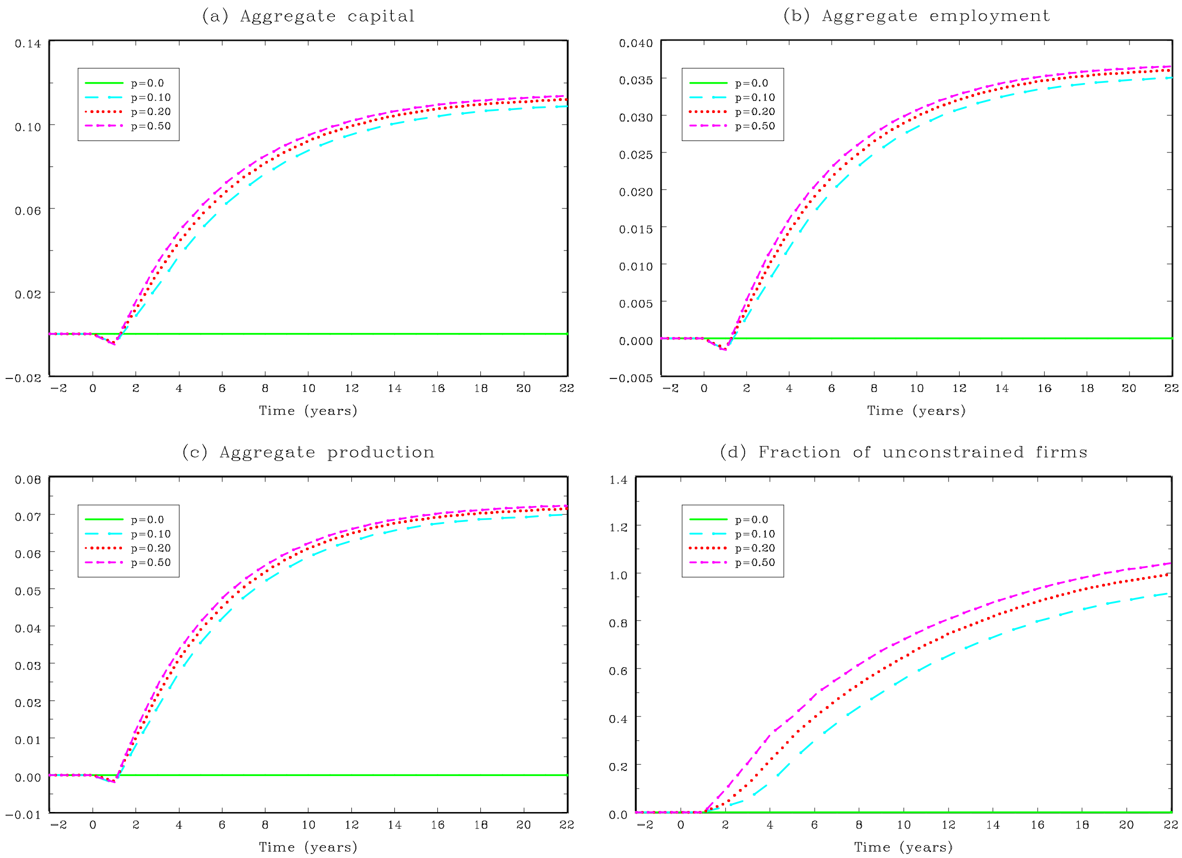


Figure 11: Impulse responses after the increase in the switching probability p.

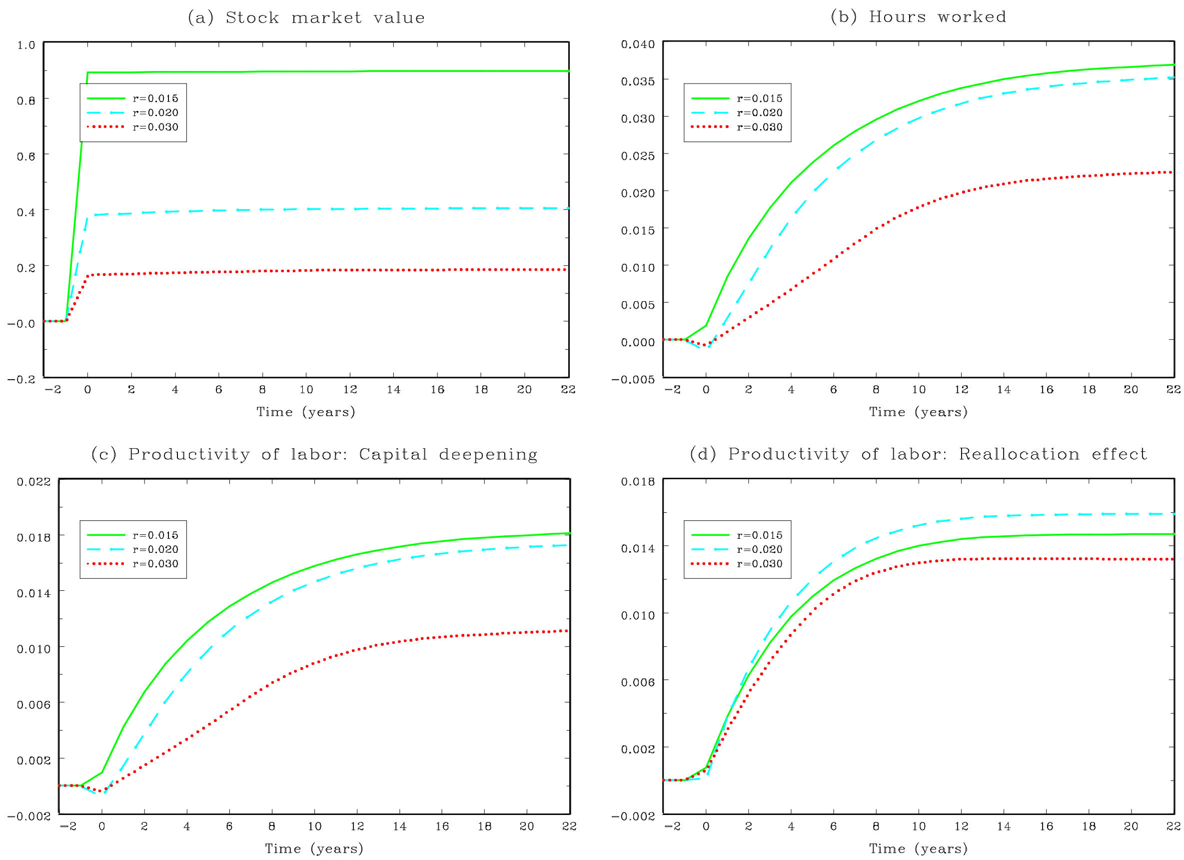


Figure 12: Sensitivity analysis for different interest rates.

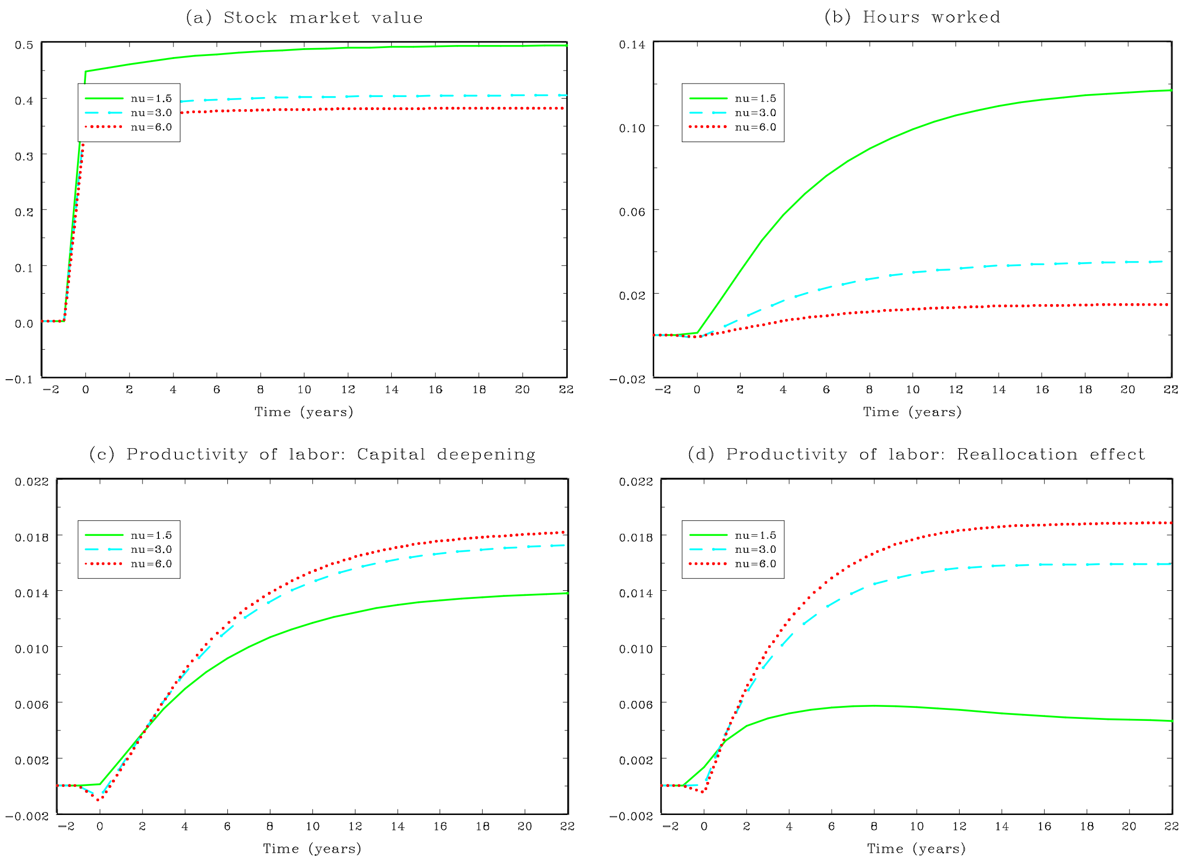


Figure 13: Sensitivity analysis for the elasticity of labor.

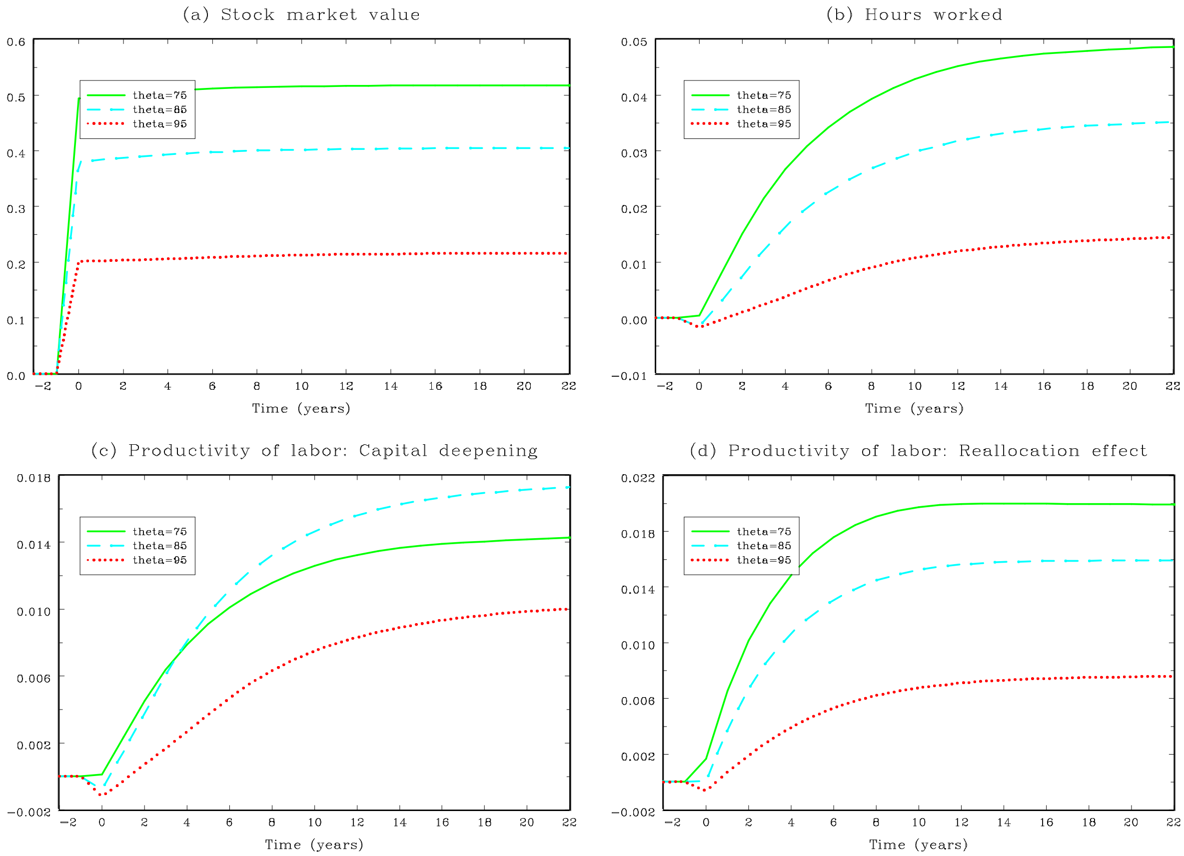


Figure 14: Sensitivity analysis for the curvature of the production function.

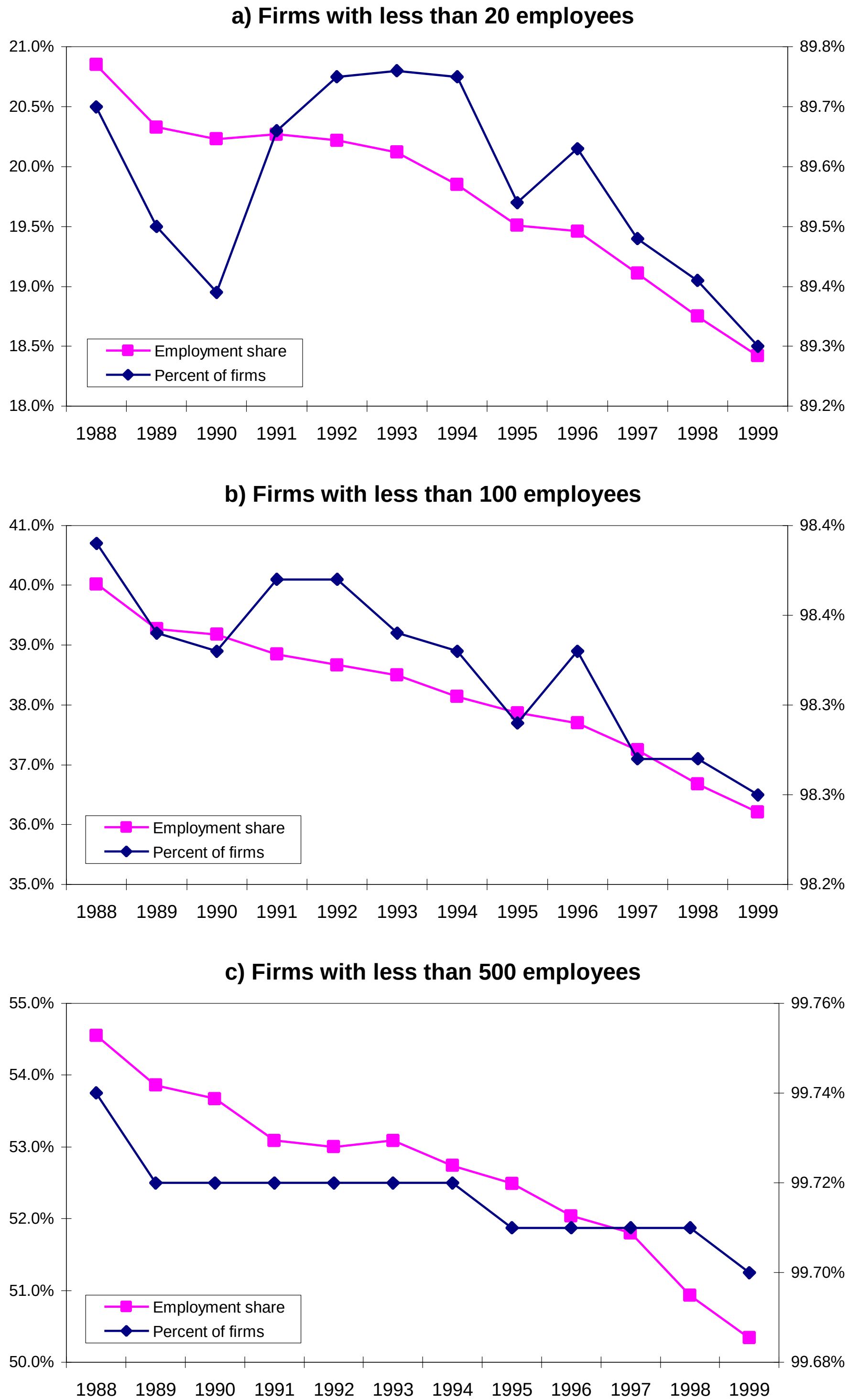


Figure 15: Dynamics in the distribution of employment among different size classes of firms.

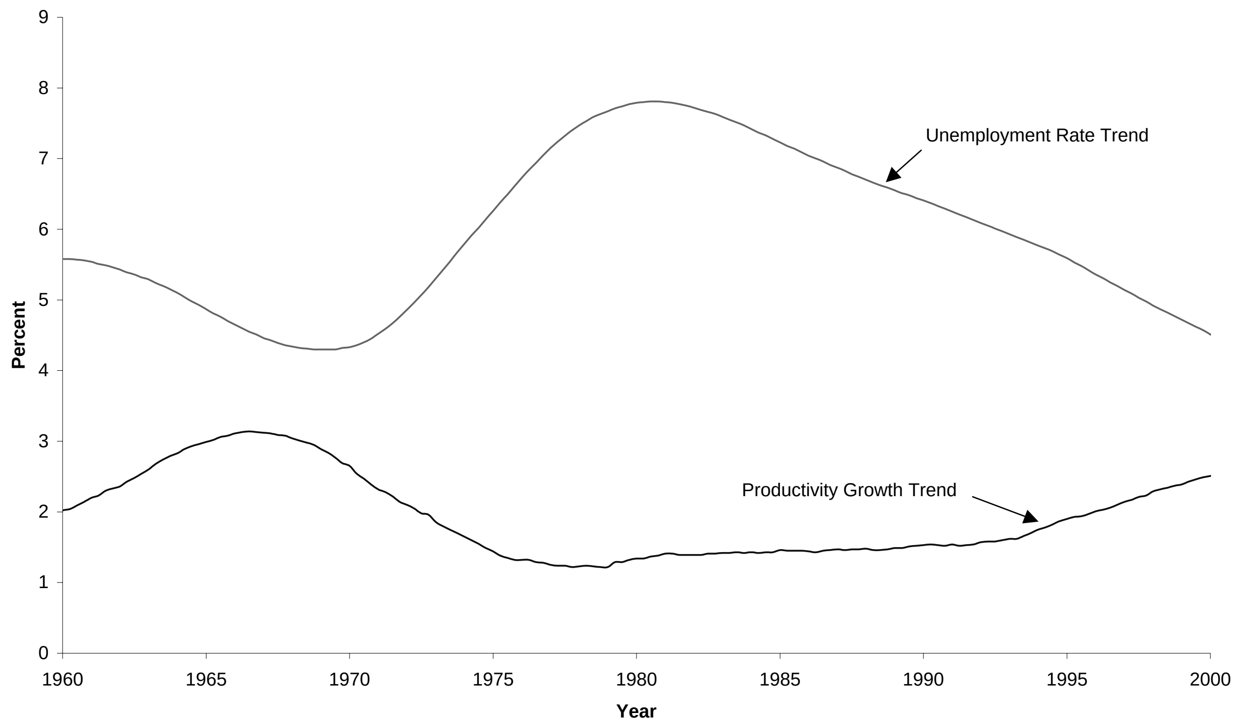


Figure 16: Trend Unemployment and Productivity Growth. (Staiger, Stock & Watson (2001))