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Abstract

Together with a sense of entering a New Economy, the U.S. 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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Stock market boom and the productivity gains of the 1990s [*][†]

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August 28, 2003

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.

JEL classification: E23, G14, G32, J23.

Keywords: New Economy, Financial Frictions, Optimal Contracts, Firm-Size Distribution, Labor Productivity.

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 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. In particular, a more concentrated firm-size distribution results in higher aggregate labor productivity.

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

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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 percent over a 5 year period, with 1 percent attributable to the reallocation effect and 1 percent to capital deepening. 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.[1]

The theoretical framework consists of a general equilibrium model in which investment projects are carried out by individual entrepreneurs and financed through optimal contracts 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 Marcet & Marimon (1992), Albuquerque & Hopenhayn (1997), Cooley, Marimon, & Quadrini (2000), Quintin (2000) and Monge (2001).

We model changes in expectations as a regime switch in the stochastic process for the growth rate of technology. This regime change leads to higher expected future growth rates while the current growth rate does not change. 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. We will discuss these alternative models in Section 6. 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 others, emphasizing, for instance, actual improvement in firm level technology that, 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. Section 3 presents the model and Section 4 contains the quantitative analysis. Section

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[1]Caballero & Hammour (2002) also study the macroeconomic implications of a stock market boom. Their transmission mechanism, however, does not relay on financial constraints. Another difference is that in their model the stock market boom is generate by asset bubbles while in our model there are no bubbles.

5 provides additional empirical evidence in support of our theory and Section 6 discusses alternative models. Finally, Section 7 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 1990-2001.

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 & Sichel (2000), the Economic Report of the President (2001) and Jorgenson, Ho, & Stiroh (2001). These numbers incorporate the downward revision of GDP made in the summer of 2001.

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)

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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.[2] Our analysis will focus on the last two components which accounted for somewhat over 4% of cumulative growth during the period 1995-00.[3]

Stock market boom: Equity prices have registered a spectacular increase during the second half of the 1990 as shown in Figure 2. During that period, the S&P500, the Dow Jones Industrial and the Nasdaq Composite indexes have more than doubled. One of the goals of this paper is to relate this stock market boom to the growth in labor productivity during this period.

Figure 3 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 three sub-periods are taken from Gordon (2001). Clearly, there is a strong positive association between productivity growth and price-earnings ratios.[4] Although the causal

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[2]Gordon (2001) further decomposes this last component into cyclical and structural, arguing that most of the gain is cyclical. Given that such a decomposition depends on additional auxiliary assumptions, we do not distinguish here between these two components although we will make this distinction in our theoretical framework.

[3]Several studies (see for example Brynjolfsson & Hitt (2000), Jorgenson & Stiroh (2000), Oliner & 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. The goal of this paper is to provide another interpretation of the driving forces underlying the improvement in multifactor productivity and capital deepening.

[4]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.

relationship can go in both directions, in this paper we will emphasize the channel going from asset prices to labor productivity.

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 these projects. 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 are 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. As shown in Figure 5, the number of IPOs and the funds raised increased during the 1990s. Therefore, there has been a clear boom in the financing of new and expanding firms.

"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 & 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 paper is to link these events in a unified framework. The driving force in our analysis will be the expectations of a New Economy.

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 following sections.

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 6. 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 given fraction of firms that are financially constrained and operate at a sub-optimal scale $\underline{L}$, and the remaining fraction includes firms that are not constrained and operate at the optimal scale $\overline{L}$. This is shown in panel a of Figure 6

a) Before the price boom b) After the price boom
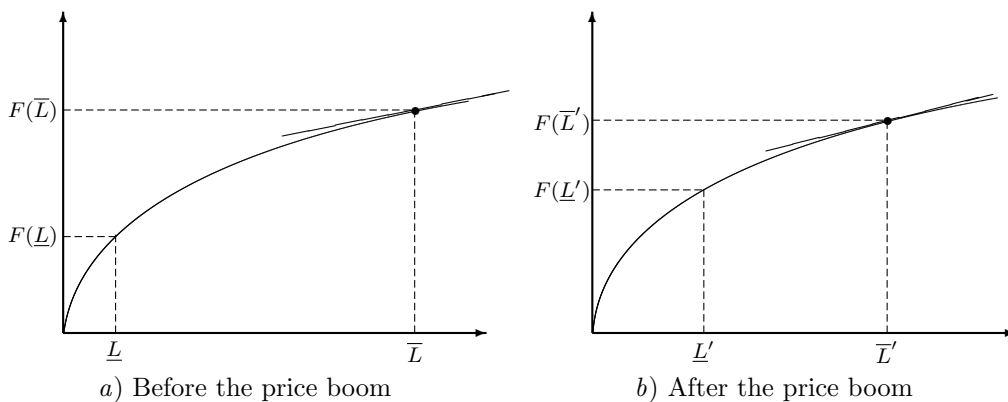
Figure 6: Reallocation of workers and productivity effect.

Because the production function is concave, this allocation of labor is clearly inefficient. By reallocating workers from unconstrained firms to constrained firms, aggregate production increases. Because the total supply of labor has not changed, the average productivity of labor must be higher.

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 more initial financing from investors. This, in turn, increases the average employment of constrained firms, which is captured by the shift to the right of $\underline{L}$ in panel b. 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 a productivity improvement and an economic expansion.[5]

In the example described above we have made two special assumptions. The first 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 is the constancy of the aggregate supply of labor. Although in the general 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 firms $\underline{L}$ 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 could induce a fall rather than an increase in the aggregate productivity of labor.[6]

Based on these considerations, we summarize here the main factors that determine the quantitative extent of a 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.

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[5]If we were to compute the Solow residuals using a constant return to scale function, $z \cdot L$, 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. We will expand on this point in Section 4.

[6]The productivity of labor does not necessarily decrease. 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 share of employment.

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 is large. This implies that the reallocation of labor can generate a large productivity gain. The number of constrained firms is obviously also important.

- **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.

3   The model

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:

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

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 $\varphi_t(0) = 0$. We also assume that this function is time dependent to guarantee a balanced growth path. We will describe the precise form of this function below.

Given the assumption of risk neutrality, r will be the risk-free interest rate earned on assets deposited in a financial intermediary.[7] Denoting by w_t the wage rate, the supply of labor is determined by the condition $\varphi_t'(h_t) = w_t/(1 + r)$. 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.

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[7]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.

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 output generated with 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 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 circumstances 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 first order Markov process. This process will be structured such that the survival of the firm declines with its age.

Financial contract and repudiation: To finance a new project the entrepreneur enters into a contractual relationship with one or more investors. The financial contract is not fully enforceable.[8] 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:

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

In this case, the firm becomes unproductive and capital fully depreciates. The fact that the firm becomes unproductive in case of diversion 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. We interpret the default value as a backyard technology that generates the present value $\lambda \cdot y_t$. 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.[9]

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

[9]Other specifications of the default value are possible. For instance, we could have used $\lambda \cdot k$. While the model would have similar properties, our specification is more convenient

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 $g_z^L < g_z^H$, and it follows a first order Markov chain. This is similar to the specification of the technology shock made in many business cycle models. In this paper, however, we deviate from the standard specification by allowing for regime switches.

We assume that the economy could be in two different regimes denoted by $i \in \{1, 2\}$. The transition probability matrices 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 $\Upsilon(i'/i)$. We interpret the 1990s as a regime switch that changed the expected future growth even if the 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, we need 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. Regarding the set up investment of a new firm we assume that it takes 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 the endogenous variables with unbounded growth will be detrended by the factor A_t.

Stock market value: 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.[10] Using this function we can now define the firm's

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because all firms will choose the same capital-labor ratio independently of the production scale. As shown in Section 4, this allows for a unique decomposition of productivity gains between capital deepening and labor reallocation. Alternatively the default value could also have an explicit forward looking component. As long as this forward looking component is not too important, it would not change our main conclusion.

[10]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. This explains why the input of

dividends with a more compact notation.

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

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

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 the whole expression by A_t, the (detrended) market 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.

Notice that, 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 at a higher rate. This, in turn, increases the value of the firm today as shown in equation (5).

Timing summary: Before starting the analysis of the model, we summarize here its timing. 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,

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labor does not depend on z_t.

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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.

3.1 The economy with enforceable contracts

We first characterize allocations 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, we will see in the next section 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.

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 states. We assume that the payments to the entrepreneur cannot be negative.

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 $A_t = \prod_{j=1}^{t}(1+g_j)$. Also, denote by $\mathbf{s}$ the aggregate states of the economy plus the individual survival probability ϕ. The contractual problem can be written recursively as follows:

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

subject to

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

$$q \geq D(k, w(\mathbf{s})) \tag{9}$$

$$c(\mathbf{s}') \geq 0, \ q(\mathbf{s}') \geq 0 \tag{10}$$

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 $(1/(1+r))R(k, w(\mathbf{s}))$. 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 formulating the above problem we take as given the optimal policy when the firm is liquidated. This policy consists of setting consumption and continuation utility equal to zero. This is the optimal policy given that the entrepreneur will permanently loose the ability to run a firm in future periods.

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 we know the wage rate $w(\mathbf{s})$ and 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 (8) and denote by γ the Lagrange multiplier associated with the enforceability constraint (9). Conditional on the survival of the firm, the first order conditions are:

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

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

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

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

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

Condition (13), combined with condition (12), implies that the payment to the entrepreneur $c(\mathbf{s}')$ is zero if the next period Lagrange multiplier $\mu(\mathbf{s}')$ is greater than zero. This has a simple intuition. Because μ decreases when the enforceability constraint is binding (see condition (12)), when $\mu(\mathbf{s}')$ reaches the value of zero, 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 shown in (11). Therefore, when $\mu(\mathbf{s}') = 0$, 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. 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 $c(\mathbf{s}')$.*

Proof 3.1 *Using the change of variable $x = k^\theta$, we can show that problem (7) is a standard concave problem. To see this, let's observe first that the optimal capital-output ratio chosen by the firm is only a function of the wage and interest rates. Therefore, the production function can be written as $y = z \cdot k^\theta \cdot \psi(w, r)$ and, with the change of variable $y = z \cdot x \cdot \psi(w, r)$. This implies*

that constraint (9) is linear in x. Because the return function is concave in x and all the other constraints are linear functions of states and choice variables, problem (7) is a standard concave problem. The uniqueness of the function $S(\mathbf{s}, q)$ 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). Q.E.D.

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 $\bar{q}(\mathbf{s})$. 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:

$$q^0(\mathbf{s}) = \max \ q \tag{16}$$
$$\text{s.t. } S(\mathbf{s}, q) - q \geq \kappa$$

This problem maximizes the value of the contract for the entrepreneur, q, subject to the participation constraint for the investor, $S(\mathbf{s}, q) - q \geq \kappa$. The solution to this problem is unique. In fact, the function $S(\mathbf{s}, q)$ is increasing and concave, and for $q \geq \bar{q}(\mathbf{s})$ its slope is 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 7. This figure plots the value of the contract for the investor, $S(\mathbf{s}, q) - q$, 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.

From Figure 7 it is easy to see 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 $S(\mathbf{s}, q) - q$. The new investor's value intersects κ at a higher level of q, and therefore, $q^0(\mathbf{s})$ increases. Because higher values of q are associated with
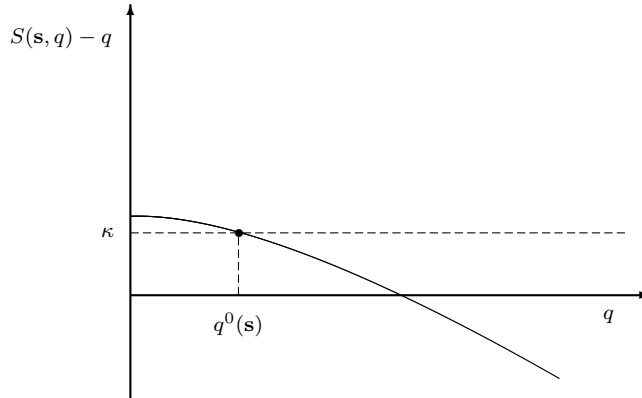
Figure 7: Initial conditions of the optimal contract.

higher values of k (remember that for constrained firms $q = D(k, w)$), this will increase the initial investment of new firms, and therefore, the aggregate stock of capital and employment will be higher. In the quantitative exercise conducted in Section 4, the increase in the value of a firm (stock market boom) is generated by a regime switch that increases the likelihood of higher future growth rates.

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_z, the current growth regime, i, and the distribution (measure) of firms over ϕ and q, denoted by M. We denote the aggregate states plus the individual survival probability by $\mathbf{s} = (g_z, i, M, \phi)$.

Definition 3.1 (Recursive equilibrium) *A recursive competitive equilibrium is defined as a set of functions for (i) consumption $c(\mathbf{s})$ and working hours $h(\mathbf{s})$ 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) $\mathbf{s}' \sim H(\mathbf{s})$. Such that: (i) the*

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household's decisions are optimal; (ii) entrepreneur's investment, consumption and wealth evolution satisfy the optimality conditions of the financial contract (conditions (11)-(15)), and the surplus satisfies the Bellman's equation (7); (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 $H(\mathbf{s})$ is consistent with the individual decisions and the stochastic process for g_z and ϕ.

4 Quantitative analysis

In this section, we calibrate the model and study how a regime switch that leads to higher expected future growth rates—the New Economy—impacts on the macro performance of the economy.

4.1 Calibration

Growth process and simulated experiment: 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 we assume that $\rho \approx 1$ and we consider several values of p.

We 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, we use the growth rate in trend productivity during the period 1972:2-1995:5 to calibrate g_z^L. As reported in

Table 1, the trend growth in labor 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 & Schlesinger (2001), the New Economy was believed to grow at rates exceeding the previous rates by as much as 1.5 percent. Accordingly, we set $g^H = (g_z^H)^{1/(1-\theta\epsilon)} = 0.029$.

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, we assume 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 we 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 for several periods 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 of the paper, that is, the fact that in the 1990s the likelihood of a 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 growth rate of technology did not change. Only the expectations about the new regime have changed. This assumption allows us to isolate the mechanism described in the paper from the effects of direct technological improvements.

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 $\alpha\phi$. We will report on the sensitivity of the results with respect to r.

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 $\nu\chi l^{\nu-1} = w/(1+r)$.

The elasticity of labor with respect to the wage rate is $1/(\nu - 1)$. 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 set $\nu = 3$ which implies an elasticity of 0.5. In the sensitivity analysis we will consider alternative values. 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, which affects the level of the equilibrium wage rate. However, for the quantities we are interested in, this parameter is irrelevant[11]

The production function is specified as $(k^{\epsilon}l^{1-\epsilon})^{\theta}$. Atkeson, Khan, & Ohanian (1996) provide some discussion justifying a value of $\theta = 0.85$. 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. 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 $\delta = 0.08$.[12]

We assume that the survival probability ϕ takes two values, $\underline{\phi}$ and $\overline{\phi}$, with $\underline{\phi} < \overline{\phi}$. When firms are born, their initial survival rate is $\underline{\phi}$. Over time, these firms may mature with some probability ξ and their survival probability becomes $\overline{\phi}$ 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 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 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

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[11]Whatever the value of e, we can set χ so that the working hours satisfy the calibration target of one third, and the labor market is in equilibrium.

[12]Notice that the economy-wide capital-output 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.

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 two parameters are important to determine the initial size of new firms: larger are these parameters and smaller is the initial size 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. We allow for this discrepancy because our model does not incorporate all the factors that could possibly explain the small size of new firms. For instance, learning is one of these factors. The parameter λ is especially important to determine the feasible range of the size distribution of firms. In particular, for small values of λ, the initial size of new 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 $\lambda = 3$, we determine the value of κ such that k_0 is 25% the capital of incumbent firms.[13] The full set of parameter values is reported in Table 2.

Table 2: Parameter values.

Survival probability of agents	$\alpha = 0.99$
Intertemporal discount rate	$r = 0.02$
Disutility from working $\varphi(h) \equiv \chi \cdot h^\nu$	$\chi = 0.002, \ \nu = 3$
Survival probability of projects	$\phi \in \{0.91, 0.99\}, \ \xi = 0.021$
Production technology $(k^\epsilon l^{1-\epsilon})^\theta$	$\theta = 0.85, \ \epsilon = 0.294$
Growth process	$g \in \{0.014, 0.029\}, \ \rho \approx 0$
Depreciation rate	$\delta = 0.08$
Set up investment	$\kappa = 0.44$
Default parameter	$\lambda = 3$

[13]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 of the paper. 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.

4.2 Simulation results

Figures 8 and 9 plot the detrended responses of several variables 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 plotted in Figure 8 show the set of events through which 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 (plot a). We will comment below how the model can generate this large stock market boom. 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).[14] A higher wage rate induces unconstrained firms to reduce employment (plot d). Also, the higher wage rate 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 $z(k^\epsilon l^{1-\epsilon})^\theta$ and choose the same capital-labor ratio, the aggregate productivity of labor can be written as:

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

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

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[14]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.

differences we get:

$$\Delta\log(\text{LabProd}) = \Delta\log z + \theta\epsilon\Delta\log\left(\frac{K}{L}\right) + \Delta\log\left(\sum_i \omega_i l_i^{\theta-1}\right) \qquad (18)$$

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

In the model, 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. As we have seen in Section 1, this corresponds roughly to about half of the actual productivity acceleration experienced by the U.S. economy during the second half of 1990s.

We would like to emphasize that 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 of equation (18)) to multifactor productivity.

Figure 9 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. As can be seen, this fraction increases after the regime switch. This is another way to see how the stock market boom relaxes the tightness of financial constraints.

4.3   Sensitivity analysis

In this section, we document the sensitivity of our quantitative results to changes in the interest rates, r, the labor supply elasticity, $1/(\nu - 1)$, and the degree of returns to scale, θ. We also provides an example that further illustrates the magnitude of the reallocation mechanism.

As we have seen in the previous section, the model can generate large stock market booms after small changes in the switching probability p. The

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calibration of the interest rate r and the survival probability ϕ are key for generating these large asset price effects. To see this, consider the steady state value of a firm once it reaches the unconstrained status:

$$P = \frac{d}{1 - \left(\frac{\alpha\phi}{1+r}\right)(1+g)} \tag{19}$$

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. As can be seen in equation (19), the value of the firm gets more responsive to changes in g as the term $\left(\frac{\alpha\phi}{1+r}\right)(1+g)$ approaches 1. Because this term depends negatively on the interest rate, smaller is r and larger is the price sensitivity to g.

The requirement for a sizable stock market increase partly motivates our specification of the survival probability ϕ as taking two values $\underline{\phi}$ and $\bar{\phi}$. Having a low survival probability for young firms allows us to generate the empirically observed high turnover rates even if mature firms have a low exit rate. The high survival rate of mature firms is important to generate large stock price movements because a large fraction of the market capitalization comes from these firms.

Figure 10 plots the stock market value and other variables for different values of the interest rates. In these impulse responses the value of the switching probability is $p = 0.2$. If we reduce the interest rate to 1.5% from our benchmark value of 2%, then 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 is close to a frictionless economy and further increases in the stock market have a modest impact on the real sector.

Figure 11 and 12 show sensitivity to changes in the labor supply elasticity and the curvature of the production function. For the labor supply elasticity, Figure 11 plots the impulse responses of the stock market and productivity for different values of the parameter ν. When labor is not very elastic, the regime switch has a larger effect on productivity but a smaller effect on aggregate employment and production. Figure 12 presents the sensitivity analysis with

respect to the returns to scale 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. When θ is small, and thus the production function more concave, the expectation of higher future growth generates larger productivity gains and larger impacts on the aggregate economy. These results confirm our discussion in Section 2.

To get a better understanding about the quantitative importance of our reallocation effect on the productivity of labor, we present here a simple example. 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. Given 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 (18) can be written as:

$$\Delta\log\left(\sum_{i=1,2} s_i L_i^{\theta-1}\right) = (\theta-1)\Delta\log(l)+\Delta\log\left[n\left(\frac{l_1}{l}\right)^{\theta} + (1-n)\left(\frac{l_2}{l}\right)^{\theta}\right] \quad (20)$$

The first term on the right-hand-side is a "level effect": given decreasing returns to scale, larger average scales reduce 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 we have 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 our calibration, we have set $\theta = 0.85$. With this value of θ, if the average labor supply increases by 1%, the average productivity of labor falls by 0.15%. In the baseline model the supply of labor increases by about 3%. Therefore, the level effect reduces productivity by about 0.45%. Table 3 shows the increase in productivity due to the relative reallocation effect (last term in equation 20), 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.

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.

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

5   Additional empirical evidence

The quantitative analysis in the previous section demonstrates our model's ability to replicate the facts documented in Section 1. Here we want to show that our model is also consistent with additional empirical observations characterizing the 1990s.

Value of new firms: A key feature of our story is that new firms receive greater initial financing and are thus able to generate higher initial values compared to incumbent firms. The entrance of new firms in our model can be interpreted as the moment in which firms get equity financing, either in the preliminary stage of venture capital financing or in the public offering stage. This last stage can be approximated by the moment in which firms get listed in the stock market. Interpreted in this way, recent data from Fama & French (2001) supports our story.

Fama & French (2001) document the market values of newly listed firms relative to incumbent firms. According to their study, 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 4, 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.

Table 4: 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 & French (2001)*

Pattern of labor share: Another feature of the model shown in panel c of Figure 9, is that the labor share of income increases after a stock market boom. This is also an empirical feature of the data as shown by Figure 13. As can be seen from this figure, the wage share of business income has increased in the second half of the 1990s. The ability of the model to capture this feature of the data will be emphasized in the next section when we discuss alternative models.

Reallocation mechanism: We provide here some more direct evidence in support of the reallocation mechanism. Table 5 reports some concentration indices for the manufacturing sector for the years 1992 and 1997. These indices are constructed using data from the 1992 and the 1997 Economic Census (which is conducted every 5 years). These indices are reported for five classes of manufacturing firms: the 50 largest; the 51st to 100th largest; the 101st to 150th largest; the 151st to 200th largest; and the remaining smaller firms. The ranking is based on value added.

Table 5 shows 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 seems to have shrunk in relative terms. This pattern is consistent with our reallocation mechanism.

Table 5 also reveals another pattern which is worth to be emphasized. 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 share of value added is smaller than the increase in share of employment. This seems to suggest that the labor productivity of the largest firms has increased relative to the productivity of smaller firms, which is consistent with our reallocation mechanism.

Table 5: Share of Industry Statistics for Companies Ranked by Value Added.

	Total employees	Production workers			Value added	New capital expenditures
		Total	Hours	Wages		
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
Other firms	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
Other firms	77.5	78.6	77.7	70.4	59.3	62.0

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

Other empirical considerations: Although these patterns seem consistent with our mechanism, some caution is needed in comparing the predictions of the model with the data. For simplicity we have assumed that all firms operate the same technology and there is only one optimal scale of production. As a result, there is a one-to-one mapping between the tightness of the financial constraints and the size of a firm. In the real economy firms are also heterogeneous in their optimal scale. This would be captured by the model if firms were heterogeneous not only in their financial status but also in z. If firms are heterogeneous in z, size is no longer an indicator of financial constraints. In fact, it is possible that firms with high values of z are on average larger but they are more financially constrained in the sense that their production scale is (relatively) farther from the optimal scale than for smaller firms.

Finally, we should also qualify one property of the model that may seem at odd with micro data. Several empirical studies have found that labor tends to be more productive in larger firms. The decreasing return feature of our model, instead, implies that the productivity of labor decreases in size. This inconsistency is only apparent because, as observed above, the size of firms in our model does not coincide with the size of firms in the

data. If we allow for heterogeneity in z, it could be possible to structure the model such that firms with large z's are larger on average but are also more financially constrained, and therefore, they are more productive. More than size, a better comparison with the data is along the age dimension. Haltiwanger, Lane, & Spletzer (1999) study a sample of single establishment firms and find that productivity falls during the first six years of life. This feature is captured by our model because over time new firm expand and get less financially constrained.

6   Alternative models

In this section, we discuss briefly whether some alternative modelling features commonly used in the business cycle literature would be able to replicate the type of responses generated by our model after a regime switch. In particular, we will discuss two modelling features: capital adjustment costs and intertemporal consumption smoothing.

Models with adjustment cost: Consider a standard adjustment cost model. In this model there is a continuum of firms with constant returns to scale maximizing the discounted values of profits and subject to adjustment costs to capital. For simplicity we maintain the assumption that agents are risk-neutral as in our model. Consumption smoothing will be discussed below. In this model, a regime switch that increases the expected future growth generates an immediate investment boom even if the productivity of the current investment does not change. This is because with adjustment costs to capital it is optimal to smooth investment.

This model is able to generate an increase in labor productivity but only through capital deepening. In fact, because of constant returns to scale, multifactor productivity does not change. Furthermore, this model cannot explain the increase in the labor income share that we have observed in the second half of the 1990s.

Notice that the alternative assumption of decreasing returns to scale would not help. In fact, due to the absence of idiosyncratic shocks, all firms operate at the same scale. Again, a regime switch will increase investment and expand the scale of production. However, the overall productivity of labor does not necessarily increase. On the one hand, workers will have more capital, which has a positive effects on productivity. On the other, the in-

crease in the scale of production decreases productivity. In this environment, if we were to measure the change in multifactor productivity assuming constant returns to scale, we would conclude that the asset price boom generates a fall in multifactor productivity.

Models with consumption smoothing: Our model abstracts from consumption smoothing considerations which can play an important role in many business cycle models. Danthine et al. (1998) extend a standard Real Business Cycle model by allowing for a regime switch similar to ours. Within their framework a positive regime switch would induce a recession (lower levels of investments, hours and outputs) rather than an expansion. The intuition for this result is simple. Because of the wealth effect, agents save less and consume more leisure. Consequently, production and investment fall.[15]

An important question, then, is whether introducing a motive for consumption smoothing into our model could overturn our results. There are two factors to consider. First, the wealth effect on leisure will reduce the supply of labor. This would make the reallocation effect larger because the wage rate increases more. Second, the incentive to increase consumption will raise the interest rate and will reduce the impact of the higher expected growth rates on asset prices. However, as long as the intertemporal elasticity of substitution is greater than 1, the market value of firms will eventually increase and this will lead to additional funding for new firms. Thus, in this case, our qualitative results will not be overturned.[16]

7   Conclusion

In this paper, we develop a general equilibrium model with financial market frictions in which stock market booms can generate an economic expansion with gains in productivity. The reaction of the economy to a stock market boom is consistent with the 1990s expansion of the US economy characterized

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[15]Danthine et al. (1998) reports only the results for the case in which there is a fall in expectations. By symmetry, higher expectations should lead to a recession.

[16]The important condition is that the intertemporal elasticity of substitution is greater than one. With CRRA preferences this would require a low degree of risk aversion. However, by using Epstain-Zin preferences, we could have a high elasticity of substitution and a high risk aversion. See Bansal & Yaron (2002) for an application of these preferences to the study of asset prices.

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, the recent survey of Baily (2002) points out that, although information and communication technologies were important for the productivity revival of the 1990s, other factors must have also played an important role. Our paper provides a complementary explanation for these productivity gains which is also consistent with the view of more recent studies emphasizing the "business reorganization" induced by greater competition. (See McKinsey Global Institute (2001) and Lewis, Palmade, Regout, & Webb (2002)). 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. The asset price boom allowed the financing of more investment for constrained firms and generated a reallocation of labor from less productive (unconstrained) firms to more productive ones.

Appendix: computation of equilibrium

Equations (11)-(15) with the initial condition $q + \kappa = S(\mathbf{s}, q)$ provide the basic conditions that need to be satisfied by the optimal contract. If we knew the terms $E(1 + g')q(\mathbf{s}')$ and $E(1 + g')S(\mathbf{s}', q')$, 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 we try to solve.

In the computation of the transitional equilibrium, we assume that $\rho = 0$. 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 growth 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 available upon request from the authors.

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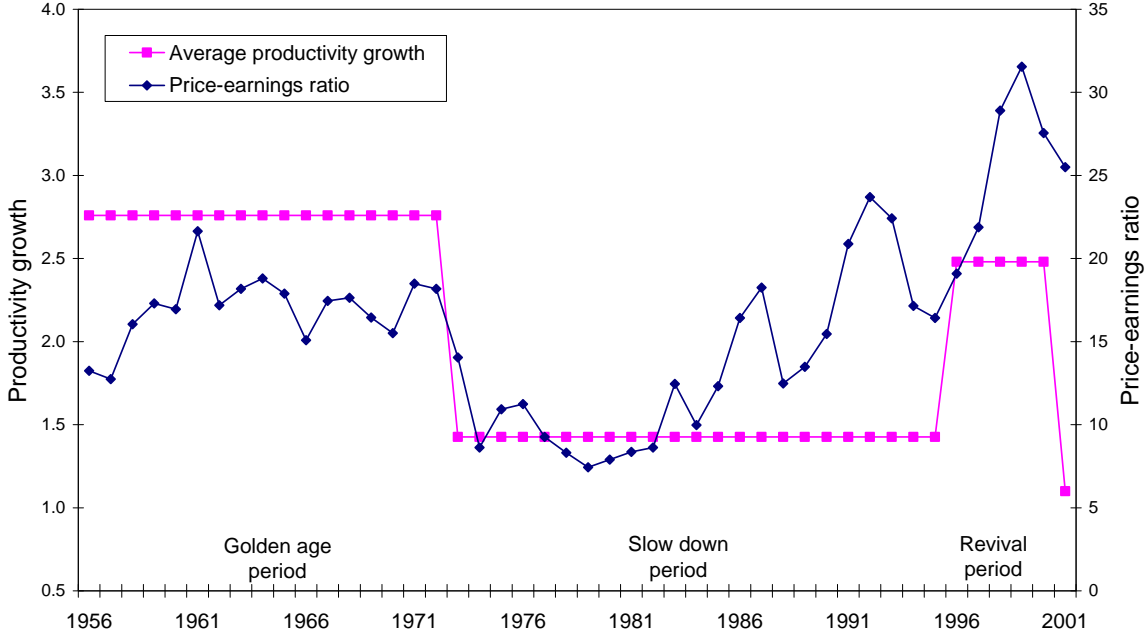# Figure 1 - Growth of macroeconomic variables
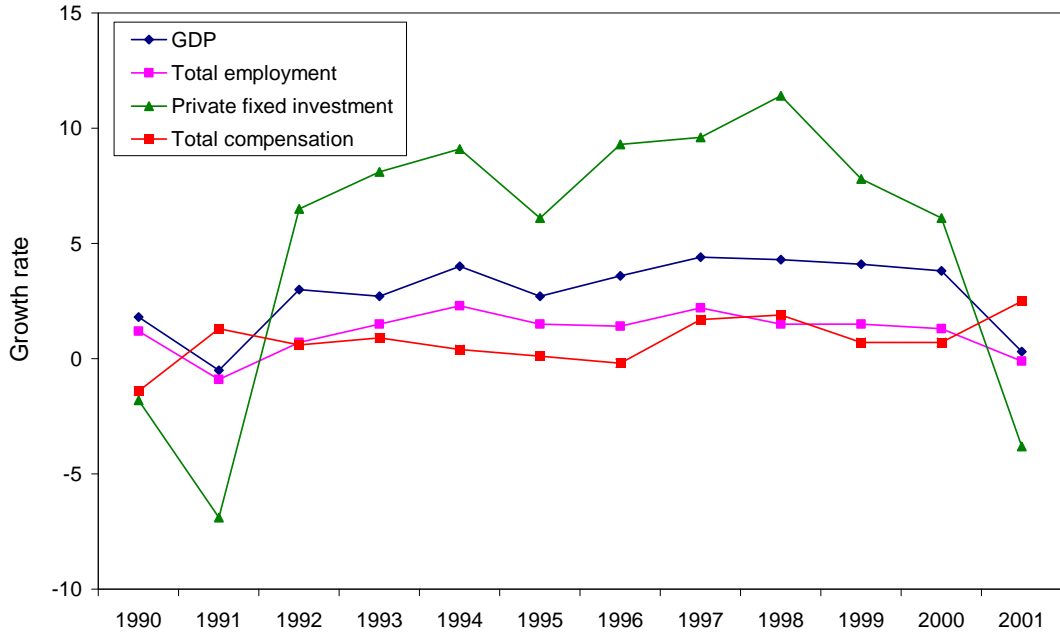
Source: Economic Report of the President and authors' updates

Figure 2 - Stock market indeces
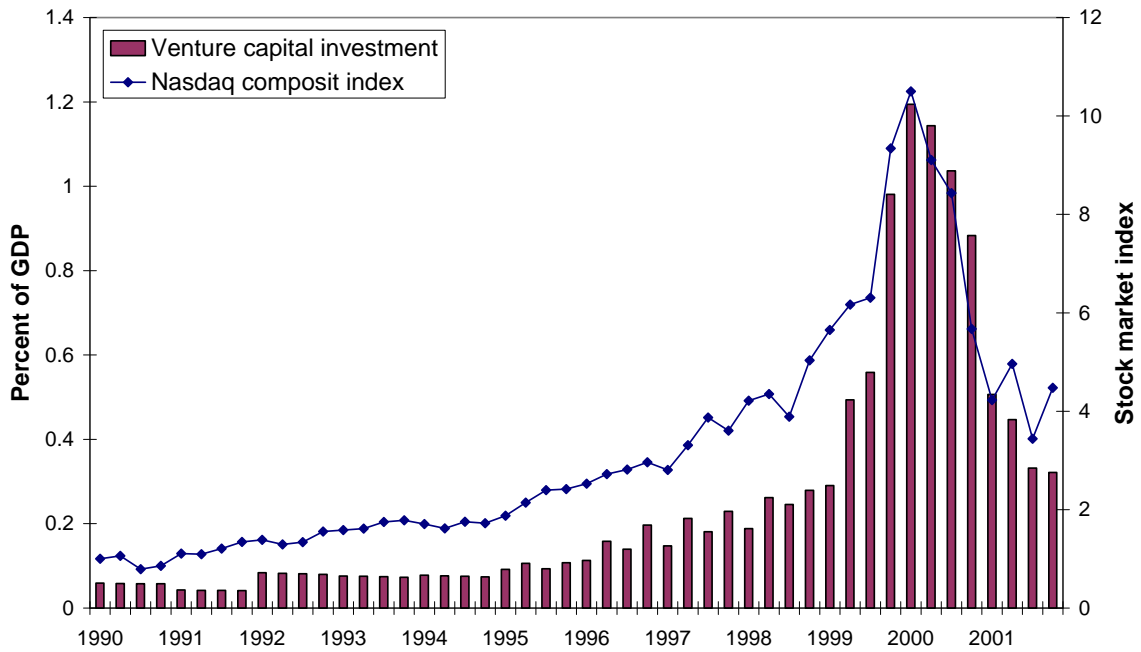(Avergare of daily closing)
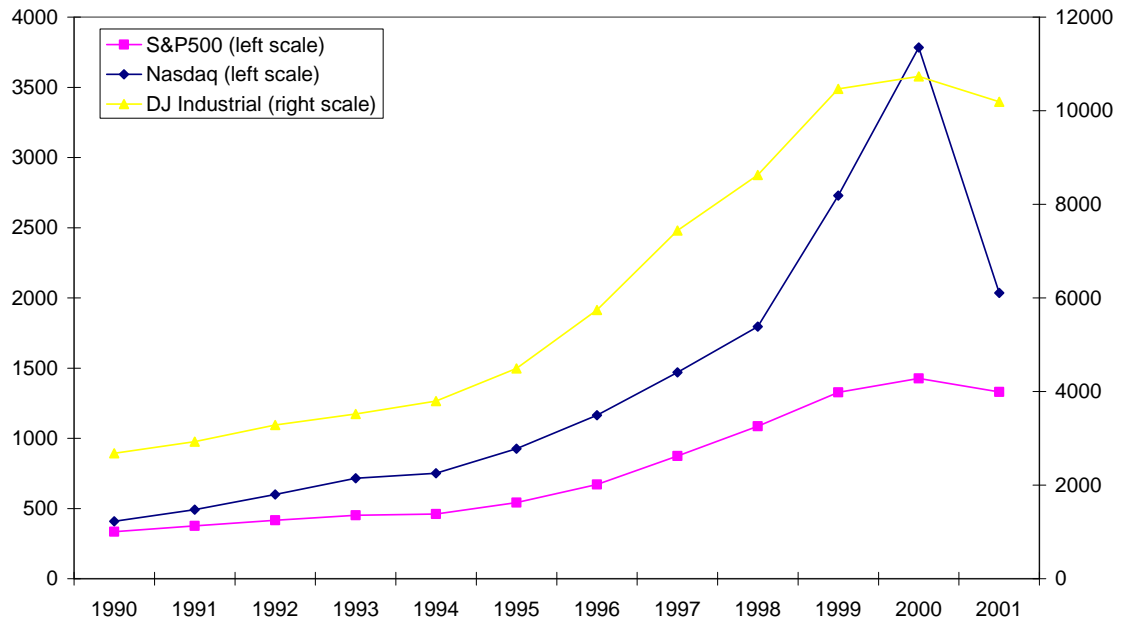
Source: Economic Report of the President

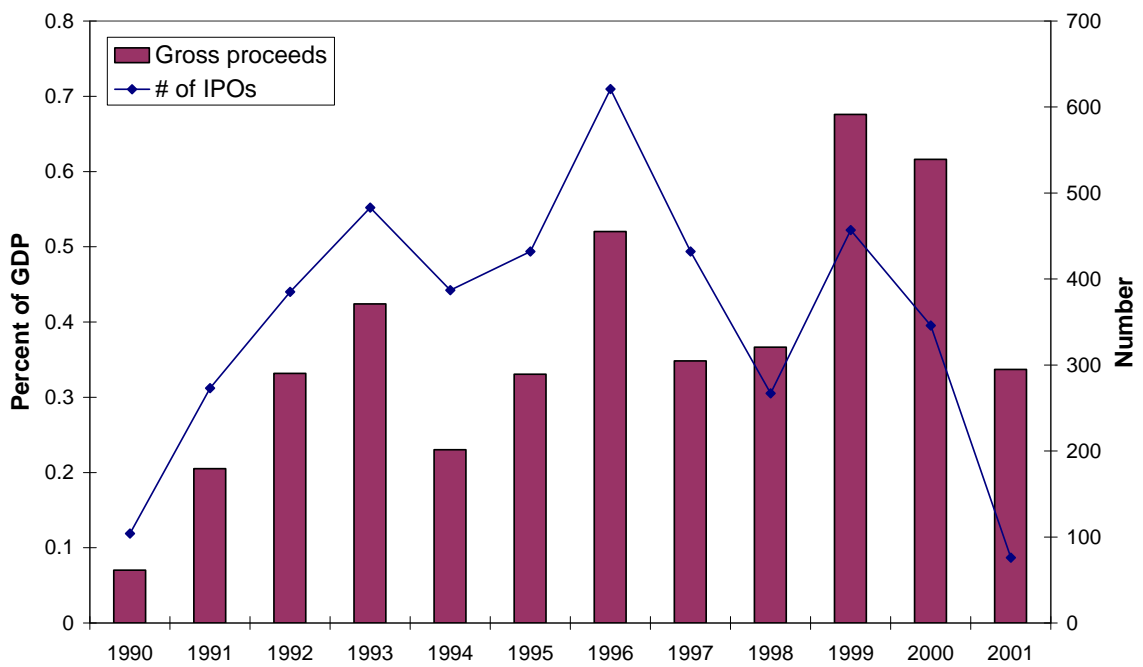**Figure 3 - Productivity growth and price-earning ratio**

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

Fugure 4 - Stock market and venture capital

Source: CRSP database and PricewaterhouseCoopers

Figure 5 - Funds raised and number of Initial Public Offerings

Source: Jay Ritter (2002), "Some Factoids About the 2002 IPO Market"

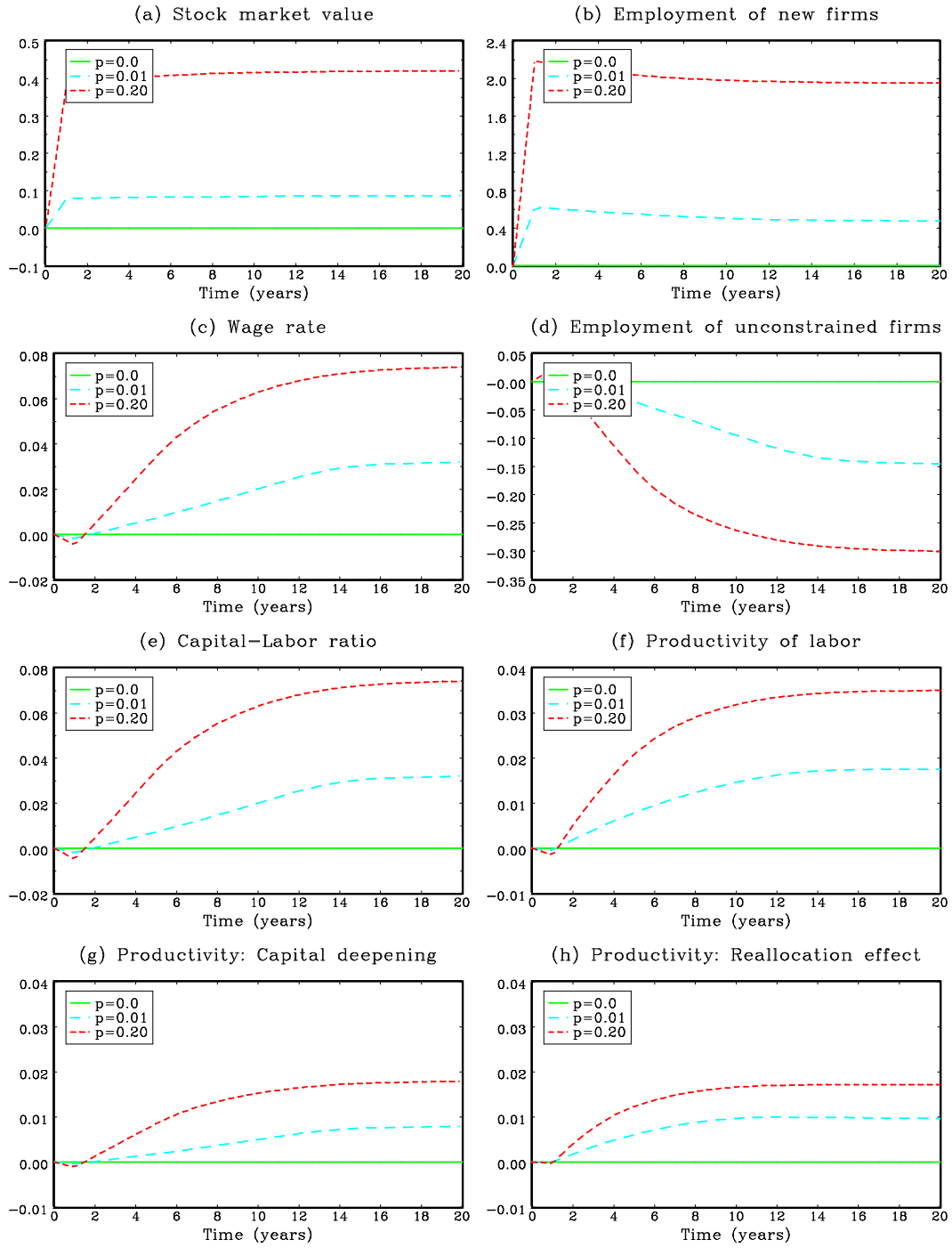# Figure 8: Impulse responses after the regime switch.

(a) Stock market value

(b) Employment of new firms

(c) Wage rate

(d) Employment of unconstrained firms

(e) Capital–Labor ratio

(f) Productivity of labor

(g) Productivity: Capital deepening

(h) Productivity: Reallocation effect

Figure 9: Impulse responses after the regime switch.

(a) Aggregate employment

(b) Aggregate production

(c) Wage share of output

(d) Fraction of unconstrained firms
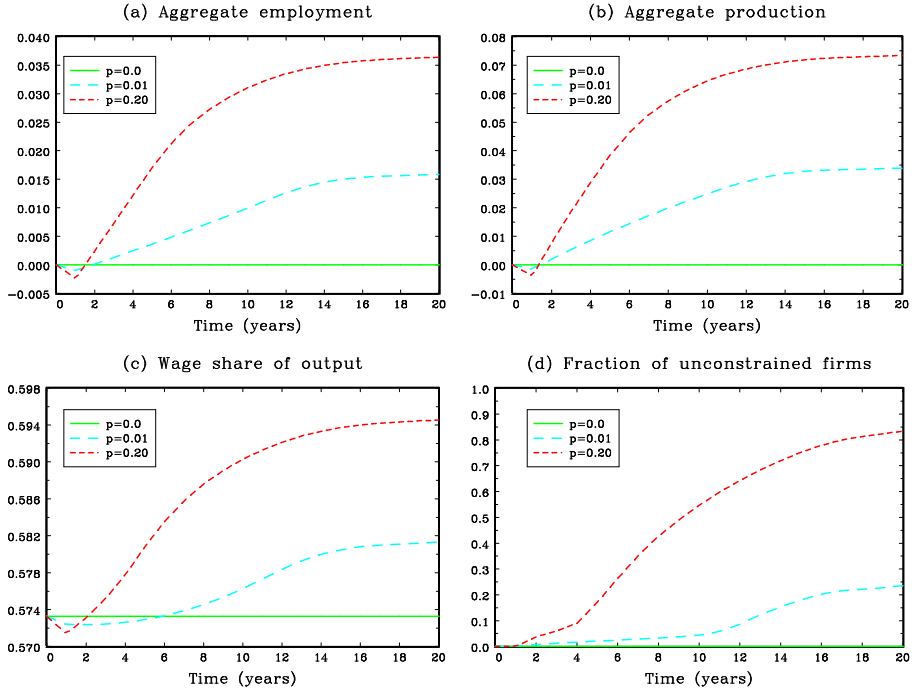
Figure 10: Sensitivity analysis for interest rates.

(a) Stock market value

(b) Productivity of labor

(c) Productivity: Capital deepening

(d) Productivity: Reallocation effect
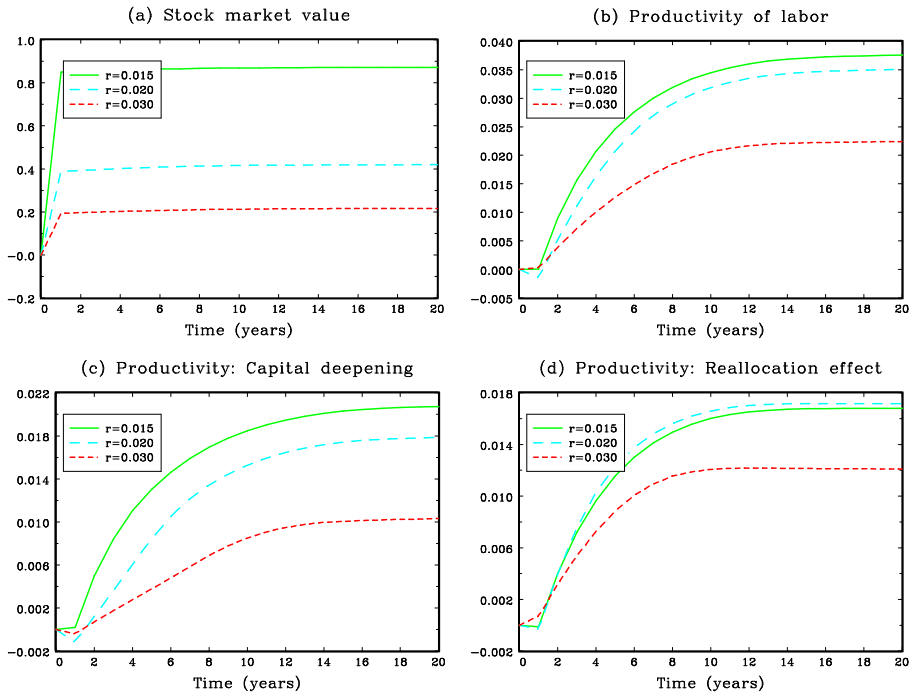
Figure 11: Sensitivity analysis for the elasticity of labor.

(a) Stock market value

(b) Productivity of labor

(c) Productivity: Capital deepening

(d) Productivity: Reallocation effect
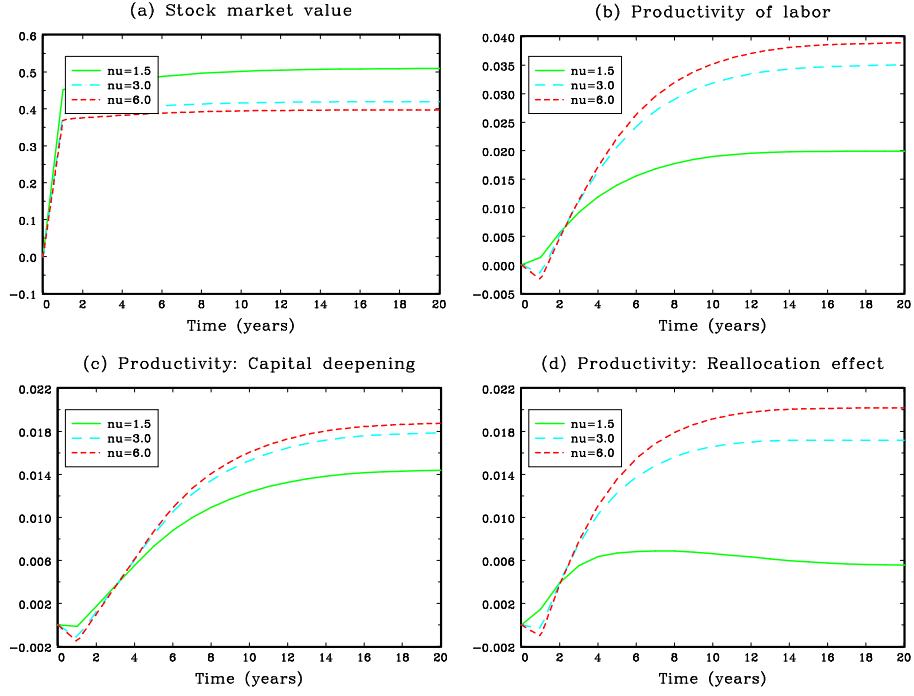
Figure 12: Sensitivity analysis for the curvature of the production function.

(a) Stock market value

(b) Productivity of labor

(c) Productivity: Capital deepening
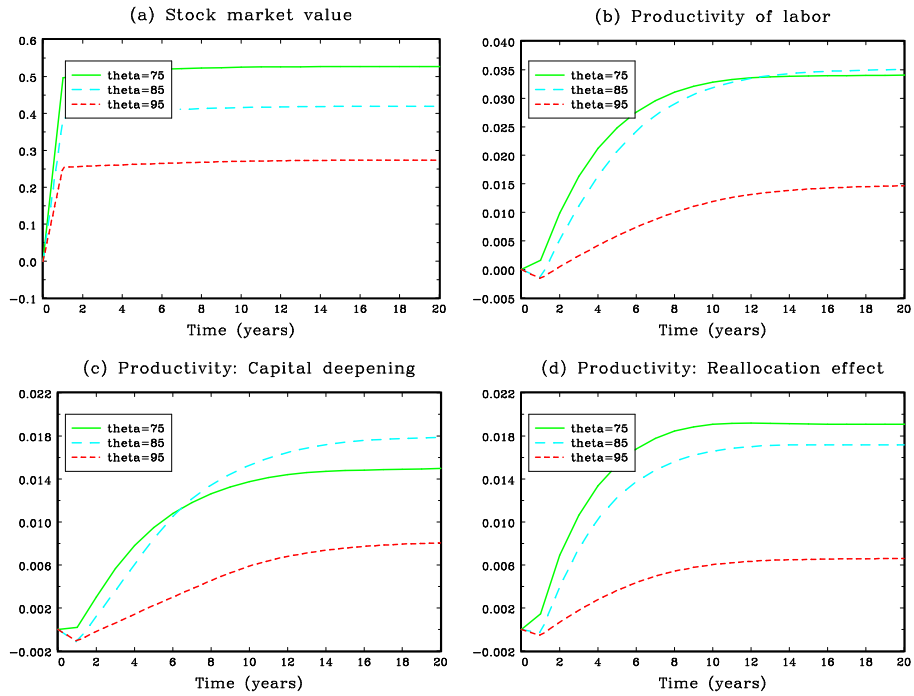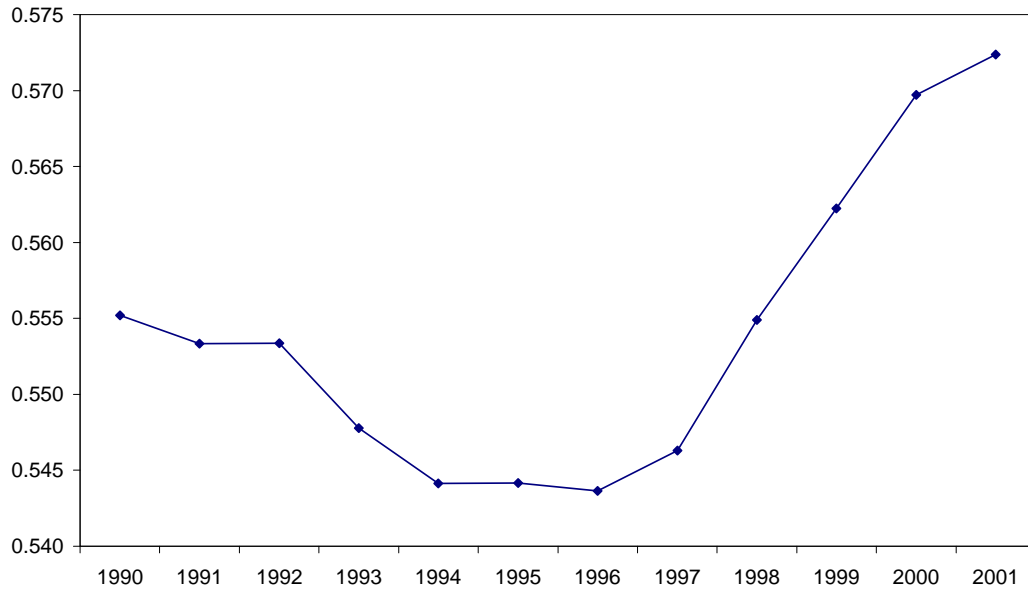
(d) Productivity: Reallocation effect

Figure 13 - Wage share in the business sector

(Percent of business income)

Source: Bureau of Economic Analysis