Productivity and Asset Prices: An Empirical Analysis of the Dot-Com Bubble*

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Abstract

Bubbles have periodically emerged in different countries. However, given their prominence, there is scant evidence on the effects of bubbles on the efficiency of firms. In this paper we analyze how the productivity of US firms was affected by the Dot-Com Bubble. We use NBER CES-manufacturing data at the industry level to compute Total Factor Productivity (TFP). We show that industries that experienced a larger bubble suffered a larger decline in TFP. This result is robust to different definitions of TFP and bubble and to the inclusion of other industry characteristics. We also show that the channel through which the bubble distorted the allocation of factors was the relative price of capital. This finding has potential implications for the current debate on how monetary policy should react to asset price bubbles.

PRELIMINARY AND INCOMPLETE

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1 Introduction

Bubbles have periodically emerged in different countries. From the Dutch Tulip Bubble in 1636 to recent housing bubbles in several OECD countries, we have witnessed plenty of booms and busts of asset prices.[1] Moreover, it has been argued that current world conditions, with weak aggregate demand that puts downward pressure to real interest rates, make the emergence of bubbles more likely.[2]

The theoretical literature on rational bubbles has contradictory predictions on the effect of bubbles on investment and productivity. In the seminal paper of Tirole (1985), bubbles emerge because there is overinvestment and, therefore, bubbles improve the market allocation by reducing aggregate investment (crowding-out effect). In contrast, more recent literature (see Martin and Ventura (2012)), introduces financial market imperfections and show that asset price bubbles may increase investment. The intuition is that, in this case, bubble have a positive reallocation effect by shifting capital away from low-productivty entrepreneurs towards high-productivty ones. When this reallocation effect offsets the crowding-out effect, bubbles will raise aggregate investment and, thus, be productivity-enhancing. Therefore, from a theoretical point of view, there is not a robust prediction on the effect of asset price bubbles on aggregate productivity.

Figure 1 represents the relationship between stock prices and aggregate Total Factor Productivity (TFP) for the United States. This figure shows that there exists a general positive correlation between stock prices and aggregate productivity, except during the Dot-Com Bubble episode (1996-2001). Indeed, during the Dot-Com Bubble, stock prices increased but the aggregate productivity of the economy sharply declined. Given this suggestive evidence, it seems interesting to ask whether bubbles have a negative effect on the efficiency of firms and which was the channel through which the bubble affected firm's choices. Particularly, if bubbles are conductive to investment, can it be that the investment is not efficient and thus firms misallocate their resources? In order to provide an answer to these questions, we use NBER CES-Manufacturing database to compute TFP at industry-level and we use CRSP database to find the bubble component of stock prices . Our baseline measure of the bubble is the drop in stock prices during the Dot-Com Bubble episode.

[1] See Kindleberger and Aliber (2005) for an historical account of different bubble episodes.

[2] See, for example, Caballero (2006) for an explanation on how bubbles may be the rational market response in a world with shortage of assets or Basco (2014) for a model in which globalization makes bubbles more likely to arise.

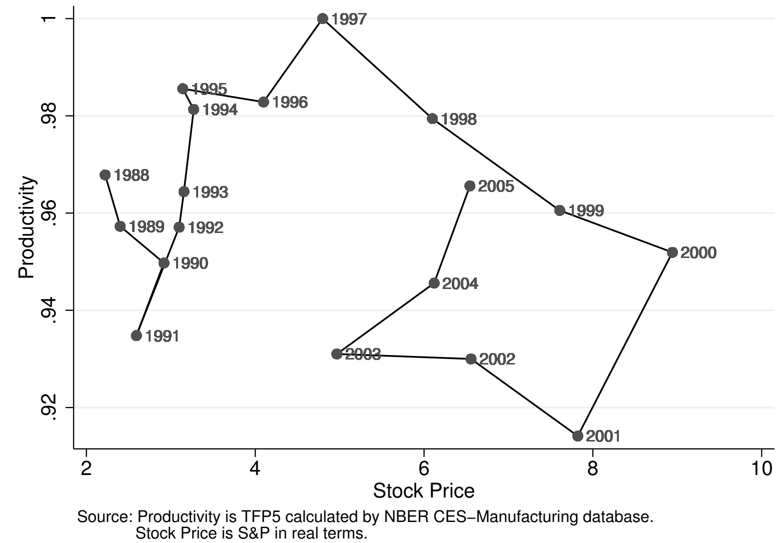

Figure 1: Stock Price and Productivity.

Before analyzing the effect of the bubble on TFP and the channel through which the bubble affected firm's choices, we provide evidence on the location of the buble and how it changed investment choices. The location of the bubble is important because it can help us understand the effects of the bubble on the economy. There exist two main accounts of the Dot-Com Bubble episode. One explanation is that the most productive firms were the ones that created the bubble. In this case, we should observe a positive correlation between the productivity of the firms prior to the bubble and the size of the bubble. We fail to find a positive correlation between both variables at industry level. A more anecdotal account of the Dot-Com Bubble puts human capital on center stage. The reason is that human capital intensive firms were seen by investors as the future pillars of the economy. Thus, this explanation would imply that bubbles emerged in human-capital intensive firms. We also fail to observe any meaningful relationship between human-capital intensity of the firm prior to the bubble and the size of the bubble. Therefore, we do not find any clear pattern on the type of industry where the Dot-Com bubble emerged. Note that our suggestive evidence does not imply that these explanations did not play a role within industries.

Then, we document that industries with a larger bubble invested relatively more in physical capital during the bubble episode. However, these industries with a larger bubble didn't invest differently either in human capital or in labor. This implies that the bubble allowed industries to invest more in physical capital. However, these correlations are not sufficient to argue whether this investment was efficient or inefficient, question in which we focus during the rest of the paper.

Our first result, is to prove that there exists a negative correlation between bubbles and change in productivity at industry-level. That is, within sectors, those industries with a larger stock price bubble experienced a larger decline in TFP. This finding is robust to different definitions of TFP, bubble and to the inclusion of other industry characteristics.

Our second result is that the channel through which the bubble distorted firms' choices is the rental price of capital. Intuitively, the bubble represented a "subsidy" to invest in physical capital. This subsidy distorted the allocation of factors and caused a decline in TFP. This finding is consistent with the recent literature on rational bubbles that emphasizes the role of bubbles in easing financial frictions (see for example, Farhi and Tirole (2012), Martin and Ventura (2012) and Basco (2014)).

The misallocation of factors is a direct consequence of observing distorted prices. We compute a bubble-adjusted TFP measure, where we control for the fact that the bubble distorted the relative price of inputs. We show that industries with a larger bubble, didn't experience a larger decline in bubble-adjusted TFP. This means that firms were optimally chosing their inputs given the prices they observed. However, these prices were distorted by the bubble.

The evidence presented in this paper reveals that while the Dot-Com Bubble was conductive to investment in physical capital, such investment was not efficient, firms misallocated their resources and the productivity of firms was reduced as a consequence.

This paper relates to different strands of the literature on bubbles and the literature on misallocation of factors. As we discussed in the introduction, recent theoretical papers (for example, Martin and Ventura, 2012) argue that bubbles may be conducive to investment and also productivity-enhancing. Our findings for the Dot-Com Bubble episode suggest that asset price bubbles may lead to investment booms by easing financial constraints but these investment booms may be inefficient. Nonetheles, it may still be true that within industries, firms with a larger buble, not only increased their investment but also experienced a larger increase in TFP. Unfortunately, we don't have firm level data.

To the best of our knowledge, this is the first attempt to empirically analyze the effect of asset price bubbles on the efficiency of firms. A close paper is Chakraborty et al. (2013) which empirically studies the real effects of the recent housing boom in the United States.

They present evidence that increases in house prices have a negative effect on the investment of firms. The intuition behind their result is that banks allocated capital towards housing and away from "real" investment. Since it has been shown, theoretically, that the effects of the bubble depend on the type of asset attached to it, see for example Basco (2014), it is not clear that their findings can be directly applied to asset price bubbles.

This paper is also related to the vast literature on the aggregate implications of misallocation of resources that followed the seminal paper of Hsieh and Klenow (2009). Hsieh and Klenow (2009) propose an empirical framework based on parametric assumptions on preferences and production technology to quantify the extent of misallocation in China and India versus the United States. In contrast, we compare the differential effect of stock prices on the efficieny of firms in the United States. A closer paper in this literature is David et al. (2013). They explicitly model the implications of imperfect information about firm-level fundamentals as a source of misallocation. We abstract from explicitly modeling how asset prices may distort the allocation of resources and instead we provide empirical evidence of a direct and significant relationship between asset price bubbles and misallocation of capital.

In Section 2, we introduce a simple model to guide the empirical section. In Section 3, we discuss the data sources and present suggestive evidence on the type of firms where the bubble emerged and the direct effects of the bubble on investment of firms. In Section 4, we present our empirical results and perform several robustness checks. Section 5 concludes.

2 Model

In this section we build a very stylized partial equilibrium model to guide the empirical section.

Consider an economy where each firm in industry i and sector s has a Cobb-Douglas production function that depends on industry TFP, capital, unskilled labor and skilled labor (or human capital):[3]

$$Y_{si} = A_{si} K_{si}^{\alpha_{K,s}} L_{si}^{\alpha_{L,s}} H_{si}^{\alpha_{H,s}}$$

[3]We have chosen a Cobb-Douglas production function for simplicity in the empirical implementation but we could consider any function F that satisfies the standard neoclassical properties. We assume that the production function is the same for all industries within a sector, therefore, capital, unskilled labor and skilled labor shares differ across sectors but not across industries within a sector.

We are agnostic on the channel through which the asset price bubble affects the problem of the firm. We just assume that the bubble may distort the relative price of inputs. We also assume that firms in each industry are price-takers, therefore, the problem of a firm in industry i is the following

$$Max_{\{K_{si},L_{si},H_{si}\}} P_{si}Y_{si} - (1+\tau_{K,i})RK_{si} - (1+\tau_{L,i})wL_{si} - (1+\tau_{H,i})vH_{si}$$

It then follows that the demand for each input $x_{si} = \{K_{si}, L_{si}, H_{si}\}$ is

$$x_{si} = \frac{\alpha_{x,s} P_{si} Y_{si}}{(1+\tau_{x,i})q_x}, \tag{1}$$

where q_x is the price of input x (for example $q_K = R$) and α_x is the elasticity of input x in production.

Total factor productivity is defined as

$$A_i = \frac{Y_i}{K_{si}^{\alpha_{K,s}} L_{si}^{\alpha_{L,s}} H_{si}^{\alpha_{H,s}}},$$

and given the demand for each input, Equation 1, it can be expressed as:

$$A_i = \prod_{x_{si}=\{K_{si},L_{si},H_{si}\}} \left[\frac{(1+\tau_{x,i})q_x}{\alpha_{x,i}P_i}\right]^{\alpha_{x,i}}.$$

What is the effect of the bubble on total factor productivity? We split this question into two subquestions: *(i)* what is the effect of the bubble on the distortions? and *(ii)* what is the effect of the distortion of total factor productivity?

To answer the second question, note that

$$\ln A_i = \sum_{x_{si}=\{K_{si},L_{si},H_{si}\}} \alpha_{x,i} \ln\left[\frac{(1+\tau_{x,i})q_x}{\alpha_{x,i}P_i}\right]. \tag{2}$$

Therefore, ceteris paribus, an increase in the distortion would have a positive effect on TFP. The intuition is that the firm is able to deliver the same quantity of the final good with less usage of inputs.

What is now the effect of bubble on the distortion? This is an empirical question which we attempt to answer later. It could be the case that it was positive for some inputs and negative for others. For now, we assume that the bubble represented a subsidy for all inputs.

Assumption 1 *The Dot-Com Bubble was a negative distortion of the price of real inputs. That is,* $\frac{\partial \tau_{X,i}}{\partial B_i} < 0 \ \forall x_i$, where B_i is the size of the bubble in industry i.

Given this assumption and our previous discussion, the next proposition on the effect of the bubble on productivity is immediate.

Proposition 1. *Industries with a larger bubble have lower productivity growth.*

Proof. It directly follows from the previous assumption and the partial derivate of A_i with respect to B_i in equation (2). □

Note that Assumption 1 is stronger than what we need for obtaining this result. We could have assumed that the "average" distortion of the bubble represents a subsidy. Formally, it would imply to assume that $\sum_{x=\{K_{si},L_{si},H_{si}\}} \alpha_{x,s} \frac{1}{1+\tau_{x,i}} \frac{\partial \tau_{X,i}}{\partial B_i} < 0$.

In the empirical section we perform two exercises. We first test the prediction that industries with a larger bubble experienced a lower increase in TFP. Then, we attempt to study the channel through which the bubble effected the allocation of inputs.

3 Data and descriptive statistics

In this section we define the variables and present descriptive statistics. In order to proceed to the empirical section we need to compute the size of the bubble in each industry and a measure of TFP.

3.1 Defining the Bubble

Although there exist a large literature on how to compute bubbles, there is no consensus on the right measure.

We know by definition that the price of a stock s is the sum of two components: the fundamental value and the bubble. That is, $S_{s,t} = F_{s,t} + B_{s,t}$. The difficult part is on finding the fundamental value of the stock, which, theoretically, is the sum of the future discounted dividends of a firm. Therefore, in order to compute the fundamental value it is necessary to know how agents form their expectations about the future of the firm and how they discount the future. In order to get rid of this problem, we assume, consistently with the literature, that there was a stock market bubble which started in 1996 and burst at some point during 2000 and 2001[4].

According with this assumption we compute, for each stock in the CRSP database traded in NYSE or Nasdaq, the bubble as the drop in the stock price during this period. That is,

$$B_s = \frac{\max(S_{s,t}) - \min(S_{s,t})}{\max(S_{S,t})} \tag{3}$$

for $t = \{January1996; ..., December2001\}$.[5] Finally, we compute the bubble for each industry i as the median of the bubble for all firms within industry i.

Figure 2 represents the bubble by each 3-digit SIC industry. Note from this figure that the bubble component was present in all the industries. In particular, the mean and standard deviation of the bubble component are 0.75 and 0.12, respectively.

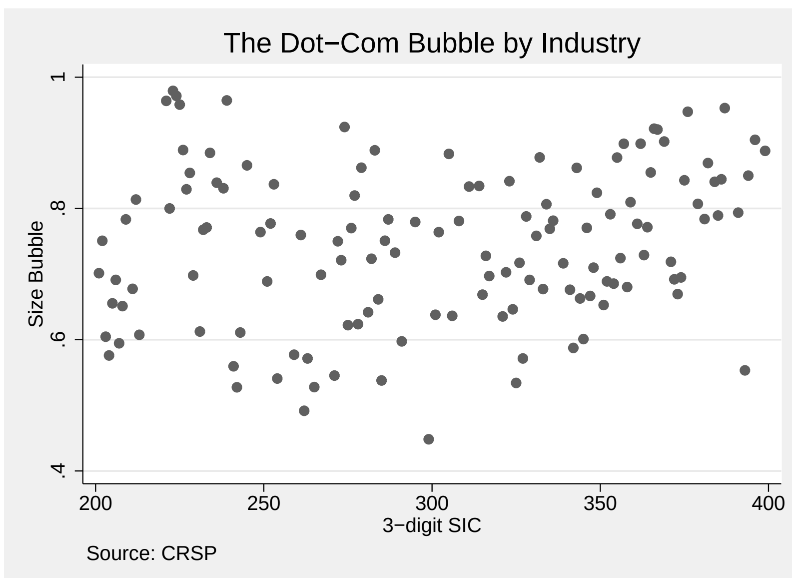

Figure 2: The Dot-Com Bubble by Industry

[4]Greenspan mentioned irrational exuberance on December 5, 1996. The peak of S&P-500 was August 21, 2000, and the bottom was September 30, 2002. NBER defines the peak of business cycle in March 2001.

[5]From CRSP, the price is the closing price of a security for the last trading day of the month, adjusted for distributions. If unavailable, the number in the price field is replaced with a bid/ask average (marked by a leading dash).

3.2 TFP Data

In order to compute the TFP at industry level, we use the NBER-CES Manufacturing Industry Database.[6] This database contains annual industry-level data over the period 1958-2009 on output, employment, payroll, other input costs, investment, capital stocks, TFP, and various industry-specific price indexes.

We compute our productivity measure using the following equation.

$$tfp_{it} = y_{it} - \alpha_l l_{it} - \alpha_h h_{it} - \alpha_k k_{it} - \alpha_m m_{it} - \alpha_e e_{it}, \tag{4}$$

where the lower-case letters indicate logarithms of, respectively, 4-digit SIC industry level TFP, gross output, labor hours, capital stocks, materials and energy inputs for industry i and year t, and α_j, for $j = l, h, k, m, e$, are factor elasticities of the corresponding inputs. Note that we also include materials and energy inputs, however we assume that firms' choices on these inputs were not affected by the bubble. We report in the appendix the exact definition of each of the variables.

Our measure of input elasticity α is the average cost shares of the sector over the 10 years previous to the start of the bubble, where a sector is defined as a 2-digit SIC code. For example, α_h is the average of the share of non-production workers wages on value added between 1985-1995 for each 2-digit SIC code. Labor, materials, and energy cost shares are computed from reported expenditures, while capital cost shares are constructed by default since we assume there are constant returns to scale.[7]

We consider our measure of TFP a robust measure of the TFP provided by the NBER database (TFP5). There are two main differences between the two measures. First, instead of using the total value of shipments as gross output, we use the total value of shipments plus the change in finished goods and work-in progress inventories during the year. Second, we adjust the payroll of employees (both unskilled and skilled) since the data on payroll does not include Social Security contributions or fringe benefits.[8]

Our variable of interest is the change in TFP during the Dot-Com Bubble. We use the median change of TFP by 3-digit SIC industry between 1996 and 2001. Figure 3 shows

[6]The NBER-CES Manufacturing Industry Database is a joint program of the National Bureau of Economic Research and the Census Bureau; http://www.nber.org/nberces/

[7]Syverson (2004) actually estimates a physical production function for ready-mixed concrete plants and finds constant returns to scale (the estimated scale elasticity is 0.996).

[8]For more details in the construction of the factor shares and the description of the variables used to compute the TFP, see the Appendix.

that TFP5 fell for almost all 3-digit industries. It is positive for only 24 out of the 128 3-digit SIC industries. The mean change is -0.062. and the standard deviation is 0.092.

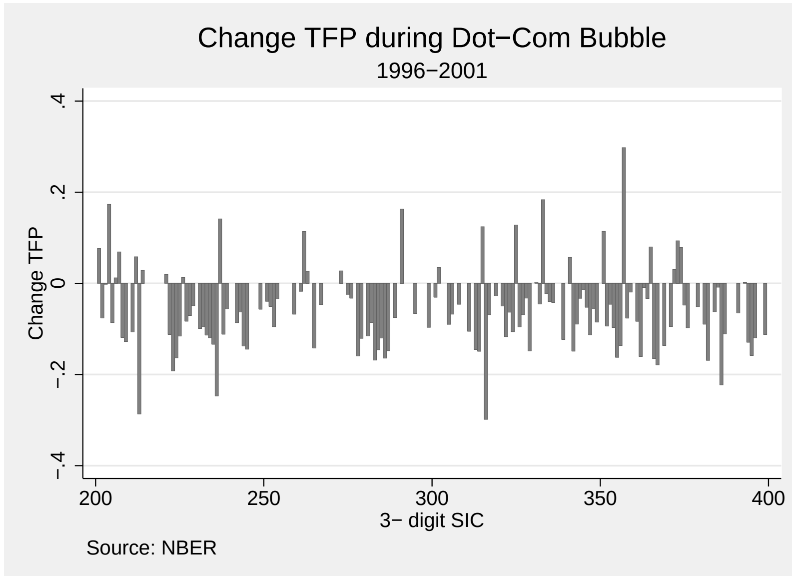

Figure 3: Change TFP during Dot-Com Bubble

3.3 Preliminary Results

In this section we provide preliminary evidence on the type of firms where the Dot-Com Bubble appeared and on how the bubble affected firm's investment choices.

An old unanswered question in the literature on bubbles is where bubbles appear. This is not an easy question, but there have been different hypotheses. For example, in Martin and Ventura (2012), the bubbles are created by the firms with the highest productivity. In contrast, the traditional account of the Dot-Com Bubble focuses on the mania in skill-intensive firms during those years.

A formal test of these hypotheses would require firm level data. Unfortunately, we only have access to industry level data. Thus, we informally test these two hypotheses by running the following regression

$$Bubble_i = \alpha + \beta X_i + \delta_s + \varepsilon, \tag{5}$$

where $Bubble_i$ is the size of the bubble in industry i, the industry characteristic X_i is TFP prior to the Dot-Com Bubble (columns 1 and 2 of Table 1) and Human Capital Intensity prior to the Dot-Com Bubble (columns 3 and 4 of Table 1). Lastly, δ_s are sector fixed effects.

Table 1 reports the coefficients of running the above regression with robust standard errors in parenthesis. Note that the coefficient on TFP (columns 1 and 2) is positive but not significant. It means that more productive industries tended to have a larger bubble, but the relationship is not significantly different from zero. Similarly, the same weak positive relationship exists between human capital intensive firms and bubble (columns 3 and 4). Therefore, we fail to find any strong evidence on the type of firms where the Dot-Com Bubble appeared. Since we do not have firm level data, these results should be taken with a grain of salt.

	Dep.Var: Bubble			
$TFP5_{1995}$	5.82			
	(6.70)			
$TFP5_{1996}$		3.93		
		(5.23)		
H_{1995}			6.35	
			(6.22)	
H_{1996}				5.98
				(6.51)
Obs.	133	133	133	133
Sector FE	Yes	Yes	Yes	Yes

Table 1: Where did the bubble appear?

The type of industries where bubbles emerged does not seem clear. However, did the bubble have a differential effect on the investment choices of firms? In order to give a first answer to this question, we run the same type of regression as above using investment in different inputs as the dependent variable. Table 2 reports the coefficients.

Note that the coefficient of the bubble is positive and significant when the dependent variable is investment in physical capital (Column 1). It means that industries with a larger bubble invested more in physical capital. Notice too that the coefficient of the bubble is not significant for investment in human capital or labor.

Thus, from this preliminary evidence we conclude that there does not seem to be a clear selection on the type of industries where the bubble appeared. However, industries with a larger bubble were able to invest more in physical capital. The remaining question is whether this differential investment was efficient. This is the question that we attempt to answer in the next section.

	Dep.Var: Investment		
	Physical Capital	Human Capital	Labor
Bubble	0.89	0.04	-0.24
	(0.36)	(0.03)	(0.30)
Obs.	133	133	133
Sector FE	Yes	Yes	Yes

Table 2: Investment Effects of the Bubble

4 Empirical Results

In this section we report our two main results. We first show that industries with a larger bubble experienced a larger decline in productivity. Then, we show that the channel through which the Dot-Com Bubble distorted firms' choices was the relative price of capital.

4.1 Dot-Com Bubble and Productivity

In this subsection we provide empirical evidence consistent with Proposition 1. That is, we show that industries with a larger bubble experienced a larger decline in TFP. In order to test this proposition, we run the following regression

$$TFP_i = \alpha + \beta Bubble_i + \phi X_i + \delta_s + \varepsilon, \tag{6}$$

where TFP_i is the change in productivity during 1996-2001 in industry i, $Bubble_i$ is the size of the bubble in industry i, X_i are other industry variables and, lastly, δ_s are sector fixed effects. Proposition 1 implies $\beta < 0$.

Table 3 presents the coefficient of the regression without additional industry variables. Standard errors are clustered at the sector level. Column 1 uses our measure of TFP and column 2 uses the measure of TFP reported in the NBER CES-Manufacturing database. Note that the coefficient of the bubble is negative and statistically significant. This implies that, within a sector, the industries which experienced a larger bubble, suffered a larger drop in productivity.

One possible concern is that the size of the bubble is only a proxy of other industry characteristics. In order to account for this possibility, Table 4 adds two industry characteristics as control variables. Namely, human- and physical-capital intensity. Note that the coefficient on the bubble remains negative and significant and it is quantitatively almost the same. The coefficient on capital-intensity is positive and significant. It means that capital-intensive industries experienced higher growth in productivity during the Dot-Com Bubble. However, we do not find any significant effect on the human-capital intensity of the industry.

It could also be argued that the industries which experienced a larger bubble were intrinsically bad industries. If this were the case, it could explain the negative coefficient on Tables 3 and 4. In order to deal with this concern, we run a placebo test. Table 5 reports the coefficient of running the same regression as in Tables 3 and 4 but the dependent variable is the change in TFP before the bubble. Note that the coefficient of the bubble is positive with both measures of TFP and it is significant when we use the TFP measured by the NBER. It means that industries which had a larger bubble did not have lower TFP growth prior to the bubble. Thus, it does not seem to be the case that the industries which had the bubble were bad industries. This is also consistent with our results in the previous section where we found a positive but not significant correlation between TFP prior to the bubble and the size of the bubble.

	TFP	TFP5
Bubble	-0.150^{**}	-0.289^{**}
	(0.0679)	(0.136)
Obs.	128	128
Sector FE	Yes	Yes

Robust standard errors in parentheses
$^{***}\ p < 0.01, ^{**}\ p < 0.05, ^{*}\ p < 0.1$

Table 3: Baseline regression : Change TFP on bubble

	TFP	TFP5
Bubble	-0.139^{**}	-0.261^{**}
	(0.0624)	(0.124)
H-Intensity	-0.0543	-0.145
	(0.0975)	(0.175)
K-Intensity	0.0338^{**}	0.0775^{**}
	(0.0148)	(0.0233)
Obs.	128	128
Sector FE	Yes	Yes

Robust standard errors in parentheses
*** $p < 0.01,^{**}$ $p < 0.05,^{*}$ $p < 0.1$

Table 4: Augmented baseline: Change TFP on bubble and H-intensity and K-intensity

	TFP	TFP	TFP5	TFP5
Bubble	0.0842	0.102	0.266^{*}	$0.284*$
	(0.0806)	(0.0788)	(0.147)	(0.147)
H-Intensity		-0.0729		-0.0764
		(0.0679)		(0.140)
K-Intensity		0.0270^{***}		0.0274
		(0.00939)		(0.0175)
Obs.	133	133	133	133
Sector FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p < 0.01,^{**}$ $p < 0.05,^{*}$ $p < 0.1$

Table 5: Placebo test: Change TFP before bubble on bubble

Therefore, the evidence presented in this section is consistent with the view that the industries with a larger bubble experienced a larger decline in TFP. In the next subsection, we attempt to identify the channel through which the bubble distorted firms' choices.

4.2 Result 2: Distortions and the Dot-Com Bubble

In our model we have assumed that the bubble represented a "subsidy" to invest in inputs, which distorted the investment choices of the firms. In this subsection we study through which relative price the bubble distorted the choices of the firms. We show that it was the relative price of capital which declined with the bubble and was responsible for the reduction in TFP.

Before reporting the results, we derive the distortions for each input and industry. Note that we can use the optimal demand of each input (Equation 1) to infer the implied distortion for each input $x = \{K, L, H\}$ and firm in industry i,

$$1 + \tau_{x,i} = \alpha_{x,s} \frac{P_{si} Y_{si}}{q_x x_{si}},$$

where $P_{si}Y_{si}$ is the nominal value of production in a firm in industry i and sector s, $\alpha_{x,s}$ is the elasticity of input x in sector s, q_x is the price of input x and x_{si} is the use of input x in a firm in industry i.

We compute the distortion at industry level as follows. First, we take logs in the expression above and compute the implied distortion at firm level (4-digit SIC). Then, to find the distortion in industry i (3-digit SIC) we compute the median distortion of all firms in industry i. Note that if inputs were optimally chosen, the distortion would be zero. That is, the actual price of input x faced by industry i differs from the optimal price by $(1 + \tau_{x,i})$.

To analyze the channel through which the bubble distorted firms' choices, we run the following regression

$$\Delta(1 + \tau_{x,i}) = \alpha + \beta Bubble_i + \phi X_i + \delta_s + \varepsilon, \tag{7}$$

where $\Delta(1+\tau_{x,i})$ is the change of the distortion in input x in industry i between 1996-2001. The rest of the variables are the same as above.

Table 6 reports the coefficients of running the above regression by the three different inputs: capital, labor and human-capital. We consider the specifications with only the bubble (odd columns) and the augmented regressions with industry controls (even columns). The dependent variable in columns 1 and 2 is the distortion in physical capital. The dependent variable in columns 3 and 4 is the distortion in labor. Lastly, the dependent variable in columns 5 and 6 is the distortion in human capital.

Note that the coefficient of the bubble is negative and significant for the distortion in physical capital (columns 1 and 2). Meaning that the industries with a larger bubble experienced a larger decline in the distortion of physical capital. In other words, industries with a larger bubble acted as if the price of physical capital had declined more.

	$\Delta ln(1+\tau_K)$	$\Delta ln(1+\tau_K)$	$\Delta ln(1+\tau_L)$	$\Delta ln(1+\tau_L)$	$\Delta ln(1+\tau_H)$	$\Delta ln(1+\tau_H)$
Bubble	-0.968^{***}	-0.964^{***}	-3.767	-4.056	-0.280	-0.464
	(0.312)	(0.282)	(2.233)	(2.512)	(2.340)	(2.207)
H-Intensity		-0.162		2.264		1.513
		(0.192)		(1.868)		(1.349)
K-Intensity		-0.126		-0.0904		0.0114
		(0.128)		(0.174)		(0.198)
Obs.	128	128	128	128	128	128
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses

*** $p < 0.01,^{**}$ $p < 0.05,^{*}$ $p < 0.1$

Table 6: Change in τ_j over the bubble period on the bubble (with and without h-intensity, k-intensity)

Notice as well that the coefficients on the rest of columns (3 to 6) are negative but not significant. This means that, indeed, the bubble reduced the perceived price of inputs but this reduction was only significantly different from zero for the distortion of capital.

The evidence presented in this section shows that the channel through which the bubble distorted firm's choices was the relative price of capital. We find that the bubble represented a subsidy to invest in physical capital, which led firms to overinvest in capital, thereby reducing its TFP.

4.3 Robustness Checks

We have argued that industries with a larger bubble experienced a larger decline in TFP and the channel through which the bubble affected firm's choices was the relative price of physical capital. We now provide a number of robustness checks to these results.

4.3.1 Alternative definition of the bubble

Our first robustness check is on the definition of the bubble. In the baseline regression, we have used the drop of the stock price as a measure of the bubble component. The rationale was that the fundamental component did not change when the bubble burst. An alternative proxy of the bubble component is the volatility of the stock price. The intuition is that the fundamental part of a stock is less volatile than the bubble component, thus, given that there was a bubble and this bubble burst, the volatility was larger in a stock price with a bubble than without a bubble. Table 7 repeats the regressions of change of TFP and the bubble using this new definition of the bubble. Notice that the coefficient of the bubble is negative and statistically significant in all the different specifications.

Table 8 repeats the regressions of the change of the distortion on the bubble. The results are also robust. We find that the coefficient on the bubble is only significant for the change in the distortion of the price of physical capital. Therefore, it confirms that the bubble represented a subsidy to invest in physical capital. Lastly, for completeness, Table 9 reports the coefficients of running the placebo test using this alternative definition of bubble. The coefficients of the bubble are not significant. This means that there is any correlation between the change in TFP prior to the bubble and the size of the bubble.

	TFP	TFP	TFP5	TFP5
Bubble	-0.0902^{*}	-0.0892^{**}	-0.176^{**}	-0.169^{**}
	(0.0461)	(0.0409)	(0.823)	(0.0643)
H-Intensity		-0.0194		-0.0931
		(0.0937)		(0.174)
K-Intensity		0.0333^{**}		0.0763^{***}
		(0.0154)		(0.0236)
Obs.	123	123	123	123
Sector FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
$^{***}\ p < 0.01, ^{**}\ p < 0.05, ^{*}\ p < 0.1$

Table 7: Baseline regression : Change TFP on bubble defined as volatility (with and without H-intensity and K-intensity).

	TFP	TFP	TFP5	TFP5
Bubble	0.0477	0.0545	0.126	0.132
	(0.039)	(0.0405)	(0.096)	(0.097)
H-Intensity		-0.0788		-0.0788
		(0.0657)		(0.132)
K-Intensity		0.0269^{**}		0.0267
		(0.00985)		(0.0186)
Obs.	128	128	128	128
Sector FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
$^{***}\ p < 0.01, ^{**}\ p < 0.05, ^{*}\ p < 0.1$

Table 9: Placebo test: Change TFP before bubble on bubble defined as volatility (with and without H-intensity and K-intensity)

	$\Delta ln(1+\tau_K)$	$\Delta ln(1+\tau_K)$	$\Delta ln(1+\tau_L)$	$\Delta ln(1+\tau_L)$	$\Delta ln(1+\tau_H)$	$\Delta ln(1+\tau_H)$
Bubble	-0.348^{***}	-0.333^{**}	-1.093	-1.263	0.669	0.561
	(0.117)	(0.133)	(1.261)	(1.378)	(1.162)	(1.250)
H-Intensity		-0.144		2.007		1.273
		(0.253)		(2.107)		(1.470)
K-Intensity		-0.129		0.0226		0.00807
		(0.135)		(0.157)		(0.199)
Obs.	123	123	123	123	123	123
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 8: Change in τ_j over the bubble period on the bubble volatility (with and without h-intensity, k-intensity)

4.3.2 Alternative definition of the change in TFP

In our baseline estimation, we have considered the total change in TFP between 1996 and 2001. However, it could be argued that since the bubble was growing over time, we should also consider a more dynamic variable. In order to address this concern we compute the mean of the interannual change in TFP during the period 1996-2001. Table 10 reports the baseline regressions using this alternative definition of change in TFP. Notice that all the results go through.

	$\overline{TFP}$	$\overline{TFP}$	$\overline{TFP5}$	$\overline{TFP5}$
Bubble	-0.0308^{**}	-0.0285^{**}	-0.0477^{**}	-0.0417^{**}
	(0.0116)	(0.0103)	(0.0204)	(0.0188)
H-Intensity		-0.00964		-0.0168
		(0.0114)		(0.0251)
K-Intensity		0.00384		0.0148^{***}
		(0.00239)		(0.00448)
Obs.	128	128	128	128
Sector FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
$^{***}\ p < 0.01, ^{**}\ p < 0.05, ^{*}\ p < 0.1$

Table 10: Average TFP growth (with and without H-intensity and K-intensity)

4.3.3 Sensitivity analysis on the return of physical capital

Since we do not know the actual gross rental rate of physical capital, we have needed to make an assumption on its value. In our benchmark, we have assumed that the gross rental price R was 10%. The rationale behind this assumption was that the real interest rate was 5% and the depreciation rate 5%. Since this assumption affects our estimates of TFP and the distortion of capital, we consider two alternative values of R as a robustness check. Table 11 reports the coefficients of running the regression of TFP and the distortion of capital for $R = 5\%$ (first column) and $R = 15\%$. (last column). In addition, for ease of exposition, we repeat our baseline assumption (second column). Note that the coefficients in all columns remain negative and significant. Thus, our results that industries with a larger bubble experienced a decline in TFP (first row) and the bubble represented a decline in the price of physical capital (second row) are robust to changes in the interest rate.

$\widehat{\beta}$	$R = 5\%$	$R = 10\%$	$R = 15\%$
ΔTFP	-0.139^{**}	-0.150^{**}	-0.158^{**}
	(0.0624)	(0.0679)	(0.0716)
$\Delta(1+\tau_K)$	-0.544^{***}	-0.968^{***}	-1.033^{***}
	(0.145)	(0.312)	(0.319)

Table 11: Robustness Checks: Different cost of capital R

4.3.4 Sensitivity analysis on the input elasticity

Our last robustness check is on the input elasticities. We have been computed these elasticities as the sectors' average cost shares over the 10 years previous to the start of the bubble. As a robustness check, we use the average cost shares over the 5 years previous to the start of the bubble and the average cost shares in 1996 (the start of the bubble). Table 12 reports the coefficient on the bubble of running our main specification for the change in TFP and the change in the distortion of physical capital with these alternative elasticities. In the first column we have our baseline measure, the second column considers the elasticities using the 5 year average and the last columns considers the elasticities of 1996, the year the bubble started. Notice that the coefficient of the bubble on all three specifications remain negative and significant.

$\widehat{\beta}$	α_{Avg10}	α_{Avg5}	α_{1996}
ΔTFP	-0.150^{**}	-0.157^{**}	-0.157^{**}
	(0.0679)	(0.0685)	(0.0691)
$\Delta(1+\tau_K)$	-0.968^{***}	-0.898^{***}	-0.871^{***}
	(0.312)	(0.276)	(0.259)

Table 12: Robustness Check: Different computations of elasticity of factors α_j

4.4 Additional Results

4.4.1 Actual vs. Measured TFP

We measured the impact of the bubble in the TFP change during 1996 and 2001, and the distortion in the marginal products of capital, human capital and labor within individual four digit manufacturing industries. In this section we aim to calculate what was the actual change in TFP during the bubble. That is, if the bubble had not induced any distortion, how would have the TFP evolved.

We have argued that the bubble distorted the relative prices of inputs, such that these distorted prices can be decomposed into: $q_x = (1 + \tau_{x,i})q'_x$ for $x = K, L, H$. Thus, to calculate the TFP without distortions (Actual TFP henceforth), instead of using q_x, we should use $q'_x = \frac{q_x}{1+\tau_{x,i}}$ for $x = K, L, H$.

In other words, the bubble affected measured TFP because it had an effect on the price of capital. However, it could be argued that, given these distorted prices, the firms were behaving optimally. In order to see whether this was case, we should find that there is no significant correlation between the size of the bubble and Actual TFP. Table 13 investigates this question. Notice that the coefficient of the bubble is not significant when the dependent variable is the Actual TFP (columns (1) and (2)). Therefore, we could conclude that firms were just responding to these distorted prices optimally but the "real" efficiency of the firm was not affected.

	Actual TFP	Actual TFP	TFP	TFP	TFP5	TFP5
Bubble	-0.0993	-0.0958	-0.150^{**}	-0.139^{**}	-0.289^{**}	-0.261^{**}
	(0.0640)	(0.0625)	(0.0679)	(0.0624)	(0.136)	(0.124)
H-Intensity		-0.0138		-0.0543		-0.145
		(0.0558)		(0.0975)		(0.175)
K-Intensity		0.0112		0.0338^{**}		0.0775^{***}
		(0.00774)		(0.0148)		(0.0233)
Obs.	125	125	128	128	128	128
Sector FE	Yes	Yes	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p < 0.01,^{**}$ $p < 0.05,^{*}$ $p < 0.1$

Table 13: Comparison between the Change in Measured TFP and in the Actual TFP on bubble (with and without H-intensity and K-intensity)

4.4.2 Policy implications: to burst or not burst?

The evidence presented in this paper is consistent with the view that asset price bubbles are bad for the economy because they distort the choices of the firms. In particular, we have shown that the Dot-Com Bubble represented a subsidy in the price of physical capital, which led industries to overinvest and therefore reduced their productivity growth.

An interesting question, which is outside the scope of the paper, is to study how Central Banks should react to bubbles. Should they ride the bubble? Should they burst the bubble? What happens when the bubble bursts?

As a first step to answer these questions, we study what did happen to the productivity of the firms right after the Dot-Com Bubble burst. Table 14 reports the coefficients of running the change in TFP during 2001-2003 with the size of the bubble and other industry characteristics.

Notice that the coefficient on the bubble is positive in all columns, although they are not significant. These results imply that the industries which had a larger bubble did not have a lower TFP growth.

Given that when there was a bubble, it distorted the optimal allocation of firms. The evidence that after the burst of the bubble those industries did not have a worse recovery would seem to point to the conclusion that it is better to burst the bubble sooner than later. However, a more careful analysis on the costs of bursting bubbles should be performed before making policy recommendations.

	TFP	TFP	TFP5	TFP5
Bubble	0.0278	0.0272	−0.0788	−0.0791
	(0.0407)	(0.0360)	(0.0583)	(0.0555)
H-Intensity		0.0147		0.0179
		(0.0571)		(0.0909)
K-Intensity		0.0178		0.0144
		(0.0123)		(0.0248)
Obs.	128	128	128	128
Sector FE	Yes	Yes	Yes	Yes

Robust standard errors in parentheses
*** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$

Table 14: The bust of the Dot-Com Bubble: Change of TFP after the bubble (2001-03) and size of the bubble (with and without H-intensity and K-intenstiy)

5 Conclusions

Asset price bubble episodes are recurrent in the world economy. However, there is scant empirical evidence on the effect of bubbles on the efficiency of the firms. In this paper we have analyzed the effects of the Dot-Com Bubble on firm's choices.

We have used the NBER CES-Manufacturing Database to compute our measure of total factor productivity (TFP) and the CRSP database to find the bubble component of the stock price at industry level.

Our first main result is to show that industries with a larger bubble experienced a larger decline in TFP. All our regressions include sector fixed effects. Moreover, this result is robust to using different definitions of TFP and including other industry control. We also have computed a placebo test. The idea is that it could be that the industries that experienced a larger bubble were worse industries and, thus, they always perform worse that the average industry. We show that this is not the case. The industries that had a larger bubble did not perform worse prior to the bubble episode.

Our second main result is to show that the channel through which the bubble distorted the firm's choice was the price of capital. That is, we show that the bubble represented a subsidy to invest in physical capital.

It would be interesting to analyze how, given that bubbles distort the efficient allocation of inputs, monetary policy should be conducted. Should central banks take action while asset prices are rising? Or should they wait until the bubble burst? We plan to pursue this question in future research.

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Appendix

Variable descriptions, measurement of input levels and input elasticities in the TFP index

The output is defined as the total value of industry shipments in millions of dollars controlling for the change in finished goods and work-in-process inventories during the year. Output and the five factors are defined as follows:

- Output is defined as the value added plus the total material costs. The value added by industry equals the sum of total shipments minus the cost of materials, plus the change in finished goods and work in process inventories during the year. Hence, by adding the total cost of materials to value added we get an output measure that controls for inventory changes. If we did not adjust by the changes in inventory, the measure would include large amounts of duplication across industries, especially machinery and transportation industries that often include production of parts as well as final products.

- Unskilled labour (L) – payroll of production workers in millions of dollars, adjusted for omitted social security or other legally mandated payments, or employer payments for some fringe benefits by scaling up for 3/2.

- Skilled labour (H) – payroll of non production workers in millions of dollars, adjusted for omitted social security or other legally mandated payments, or employer payments for some fringe benefits by scaling up for 3/2.

- Materials (M) – cost of non-energy materials in millions of dollars.

- Energy (E) – expenditures purchased fuels and electrical energy in million of dollars.

- Capital (K) – total capital stock.

The five costs shares (α_j) vary by industry by year, and are defined as:

(α_L) Production workers: (3/2)*prodw/output
(α_H) Non production workers: (3/2)*prodh/output
(α_E) Energy: (3/2)*energy/output
(α_M) Materials: (3/2)*(macost-energy)/output
(α_K) Capital: 1- α_L- α_H- α_E-α_M

List of sectors

SIC	Name
20	Food and kindred products
21	Tobacco products
22	Textile mill products
23	Apparel and other textile products
24	Lumber and wood products
25	Furniture and fixtures
26	Paper and allied products
27	Printing and publishing
28	Chemicals and allied products
29	Petroleum and coal products
30	Rubber and miscellaneous plastic products
31	Leather and leather products
32	Stone, clay, and glass products
33	Primary metal industries
34	Fabricated metal products
35	Industrial machinery and equipment
36	Electronic and other electric equipment
37	Transportation equipment
38	Instruments and related products
39	Miscellaneous manufacturing industries

Tables

	Top			Bottom	
SIC	Name	Size	SIC	Name	Size
223	Broadwoven Fabric Mills, Wool	.98	325	Structural Clay Products	.53
224	Narrow Fabric Mills	.97	265	Paperboard Containers and Boxes	.53
239	Fabricated Textile Products	.96	242	Sawmills and Planning Mills	.53
221	Broadwoven Fabric Mills, Cotton	.96	262	Paper Mills	.49
225	Knitting Mills	.96	229	Miscellaneous Textile Goods	.45

Table 15: List of industries with the largest and lowest bubble

	Top			Bottom	
SIC	Name	ΔTFP	SIC	Name	ΔTFP
357	Computer and Office Equipment	.29	223	Broadwoven Fabric Mills, Wool	-.19
333	Primary Smelting Nonferrous Metals	.18	386	Photographic Equipment	-.22
204	Grain Mill Products	.17	236	Girls' and Children's Outwear	-.25
291	Petroleum Refining	.16	213	Chewing and Smoking Tobacco	-.29
325	Structural Clay Products	.13	316	Luggage	-.30

Table 16: List of the industries with the highest and lowest change in TFP